North Coast Watershed Assessment Program

DRAFT

Redwood Creek Watershed Synthesis Report

The mission of the North Coast Watershed Assessment Program is to conserve and improve California's north coast anadromous salmonid populations by conducting, in cooperation with public and private landowners, systematic multi-scale assessments of watershed conditions to determine factors affecting salmonid production and recommend measures for watershed improvements.

Public Review Draft

2001
Redwood Creek Water Quality Assessment

Compiled for the
North Coast Watershed Assessment Program

DRAFT

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The North Coast Regional Water Quality Control Board would like to thank staff from the Redwood National and State Parks, USGS Pacific Northwest Research Station, Barnum Timber Company and Simpson Timber Company for their contributions to the NCWAP 2001 water quality assessment of Redwood Creek.

Also, much thanks goes out to the Redwood Creek NCWAP 2001 team. We put out a great effort and had a great time working together.

Last, but not least, thanks to my co-workers at the NCRWQCB who helped me get this report together. I could not have done this without your support.

- **OVERALL CONCLUSIONS**
  - Sediment is known to be a major source of impairment to the proper function of the watershed for salmonid production. Data from 20 years taken from 40 mainstem and tributary sites show that sediment continues to be a threat.
  - Temperature is impaired along the mainstem as shown by data from five mainstem sites with up to five years of continuous monitoring data. Temperatures may also be impaired at tributaries in the middle, lower, and estuary areas of the watershed as shown by data from data sampled from 28 tributary sites.
  - Water quality, as it relates to DO, pH, conductance, etc., fell within the accepted ranges for Basin Plan water quality objectives. Water quality data for suspended sediment, turbidity, pesticides and herbicides were not available or not examined for this assessment.
  - Increased biological sampling, including macroinvertebrates and bacteria, and fine sediment, including suspended sediment and turbidity, is necessary to fully assess water quality.

- **METHODS**

The Regional Water Quality Control Board (RWQCB) compiled and evaluated existing data that were available as well as collected new water quality data. The data analysis included in this assessment by RWQCB is for basic water chemistry, water temperature, and sediment parameters. The data gathering, data collection, and data analysis techniques are detailed in our methods manual (RWQCB 2001).

Data Gathering

Data gathering is the process of compiling existing data from Regional Water Board files, other agency files, and other sources. The Regional Water Board has several types of water quality information sources within its office, all of which were evaluated for inclusion into the assessment: Timber Harvest Plan files, water quality monitoring files, TMDL files, grant files, EIRs and other reports. Sources outside the office included data and reports from other agencies (including water rights and diversion information), US EPA's StoRet water quality database, watershed groups, landowners, and public interest groups. As data were gathered, the location and general characteristics of the data were catalogued in a computerized database. Catalogued data included non-water quality data related to the watershed assessment that was made available to the other NCWAP agencies as requested.

Data Collection

RWQCB staff collected water quality measurements three times during 2001 in the Redwood Creek watershed. Sample collection and analysis was in accordance with methods used by USGS and USEPA. Those methods are explained and referenced in the RWQCB's NCWAP methods manual (RWQCB 2001). While staff hoped to collect stream channel information, such as pebble counts, we were unable to accomplish this due to access and resource constraints. However, a Redwood National and State Parks (RNSP) and RWQCB joint effort in temperature monitoring resulted in an additional site being monitored in 2001 as well as the collection of air temperature data for future modeling activities.

Data Analysis

The water quality analysis included comparison of available data to water quality objectives from the Basin Plan, Total Maximum Daily Load suggested targets, and EMDS dependency relationships (thresholds) and other ranges and thresholds derived from the literature (Table 1). With the exception of the Basin Plan objectives, these ranges and thresholds are not legal regulatory numbers. Rather, they are based on information available at the time and are expected to change as new data and analyses become available.

The data were digitized into formats appropriate for the information, e.g., spreadsheets for dissolved oxygen, percent fines, and temperature. Analysis of the data was specific to the data type and its quality. For example, water temperature data from continuous data loggers were evaluated from raw data plots over time and cumulative distribution plots against water quality criteria or water quality objectives (WQOs) to determine frequency of exceedances (percent of observations and number of days), duration of exceedances (how many hours was a particular standard exceeded in a day), and maximum daily excursions. [not all of this has been done yet] Additionally, summary statistics were compared to the limiting factors thresholds: MWAT, the maximum 7-day floating average temperature for the summer season for a site and the Seasonal Maximum for a site. Where we did not have the full raw data set for continuous temperature measurements, we evaluated only the summary statistics.

The temperature range for “fully suitable conditions” of 50-60F(10-15.6C) was developed as an average of the needs of several cold water fish species, including coho salmon and steelhead trout. As such, the range does not represent fully suitable conditions for the most sensitive cold water species (usually considered to be coho) (Armour, 1991; Lewis, et al., 2000).

Peak temperature plots were also derived from data gathered from various sources. Peak temperatures are important to consider as they may reflect short term thermal extremes that, unless salmonids are able to escape to cool water refugia, may be lethal to fish stocks. The literature supports a critical peak lethal temperature threshold of 75F (24C), above which death is usually imminent for many Pacific Coast salmonid species (Brett, 1952; Brungs and Jones, 1977; RWQCB, 2000; Sullivan, et al., 2000).

For sediment parameters, we used data available for streambed cores and pebble counts. The primary metrics used to analyze percent of fine material in core samples was <0.85 mm and <6.5 mm. The thresholds were maximum of 14% and 30% respectively for the two sediment core sizes (from the Redwood Creek TMDL, USEPA 1998). We applied the TMDL targets where data for corresponding targets were available and attempted to evaluate other fractions by deductive reasoning. For example, if a target for fines <6.5mm is <30% and the percentage of fines <4mm was measured as 50%, then the <6.5mm target was exceeded.

As the synthesis of data proceeded, these data were evaluated with respect to influential factors, such as canopy for temperature and land use and erosional features along with fluvial geomorphology for sediment. As such, it was an interdisciplinary effort in recognizing and hypothesizing the linkages and understanding the data more fully on a broader context.

- **WATER QUALITY ASSESSMENT**

Existing water quality requirements are described in the North Coast Water Quality Control Board Basin Plan (RWQCB 1996), which is the tool for comprehensive water quality planning as set forth in both California's Porter-Cologne Water Quality Control Act and the federal Clean Water Act. Among other things, the Basin Plan describes the existing and potential beneficial uses of the surface and ground waters in each of the watersheds throughout the North Coast Region. It also identifies both numeric and narrative water quality objectives, the attainment of which is considered essential to protect the identified beneficial uses.
The Basin Plan identifies the following existing beneficial uses of water in the Redwood Creek basin:

- Municipal and Domestic Supply (MUN)
- Agricultural Supply (AGR)
- Industrial Service Supply (IND)
- Recreational Uses (REC-1 & REC-2)
- Commercial and Sport Fishing (COMM)
- Cold Freshwater Habitat (COLD)
- Wildlife Habitat (WILD)
- Rare, Threatened, or Endangered Species (RARE)
- Migration of Aquatic Organisms (MIGR)
- Spawning, Reproduction, and/or Early Development (SPWN)
- Estuarine Habitat (EST)

The beneficial uses identified above as COMM, COLD, MIGR, WILD, RARE, SPWN, and EST are all related to the Redwood Creek watershed cold water fisheries. Beneficial uses associated with the cold water fisheries appear to be the most sensitive in the watershed. As such, protection of these beneficial uses is presumed to protect any of the other beneficial uses that might also be harmed by sedimentation.

The COMM beneficial use applies to water bodies in which commercial or sport fishing occurs or historically occurred for the collection of fish, shellfish, or other organisms, including, but not limited to, the collection of organisms intended either for human consumption or bait purposes. The COLD beneficial use applies to water bodies that support or historically supported cold water ecosystems, including, but not limited to, the preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. The WILD beneficial use applies to water bodies that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources. The RARE beneficial use refers to water bodies that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered. The MIGR beneficial use applies to water bodies that support or historically supported the habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish. The SPWN beneficial use applies to water bodies that support or historically supported high quality aquatic habitats suitable for the reproduction and early development of fish. The EST beneficial use applies to water bodies that support or historically supported estuarine ecosystems, including, but not limited to, the preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

Water Quality Objectives

The Porter-Cologne Water Quality Control Act (California Water Code §13000 et seq.) specifies that each regional board shall establish water quality objectives which, in the regional board's judgment, are necessary for the reasonable protection of the beneficial uses and for the prevention of nuisances. The water quality objectives are considered to be necessary to protect those present and probably future beneficial uses stated above and to protect existing high quality waters of the state. As new information becomes available, the Regional Water Board will review the appropriateness of existing and proposed water quality objectives and amend the Basin Plan accordingly.

The following is a summary of water quality objectives for the Redwood Creek watershed according to the Basin Plan, as amended in 1996.

Table 1: Narrative water quality objectives

Objective	Description
Color	Waters shall be free of coloration that causes nuisance or adversely affects beneficial uses.
Tastes and Odors	Waters shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to fish flesh or other edible products of aquatic origin, or that cause nuisance or adversely affect beneficial uses.
Floating Material	Waters shall not contain floating material, including solids, liquids, foams, and scum, in concentrations that cause nuisance or adversely affect beneficial uses.
Suspended Material	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Settleable Material	Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses.
Oil and Grease	Waters shall not contain oils, greases, waxes, or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses.
Biostimulatory Substance	Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.
Sediment	The suspended sediment load and suspended sediment discharge rate of surface water shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
Temperature	The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of any COLD water be increased by more than 5F above natural receiving water temperature.
Toxicity	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life.
Pesticides	No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. There shall be no bioaccumulation of pesticide concentrations found in bottom sediments or aquatic life.
Chemical Constituents	Waters designated for use as agricultural supply (AGR) shall not contain concentrations of chemical constituents in amounts which adversely affect such beneficial uses.
Radioactivity	Radionuclides shall not be present in concentrations which are deleterious to human, plant, animal or aquatic life nor which result in the accumulation of radionuclides in the food web to an extent which presents a hazard to human, plant, animal, or indigenous aquatic life.

TABLE 2: NUMERIC WATER QUALITY OBJECTIVES

Objective	Description
Turbidity	Turbidity shall not be increased more than 20 percent above naturally occurring background levels.
pH	The pH of waters shall always fall within the range of 6.5 to 8.5.
Dissolved Oxygen	At a minimum, waters shall contain 7.0 mg/L at all times. Ninety percent of the samples collected in any year must contain at least 7.5 mg/L. Fifty percent of the monthly means in any calendar year shall contain at least 10.0 mg/L.
Bacteria	The bacteriological quality of waters of the North Coast Region shall not be degraded beyond natural background levels. Based on a minimum of not less than five samples for any 30-day period, the median fecal coliform concentrations in waters designated for contact recreation (REC-1) shall not exceed 50/100 ml. Nor shall more than ten percent of total samples during any 30-day period exceed 400/100 ml.
Specific Conductance	Ninety percent of the samples collected in any year must not exceed 220 micromhos at 77F. Fifty percent of the monthly means in any calendar year shall contain at least 125 micromhos at 77°F.
Total Dissolved Solids	Ninety percent of the samples collected in any year must not exceed 115 mg/L. Fifty percent of the monthly means in any calendar year shall contain at least 75 mg/L.

Prohibitions

In addition to water quality objectives, the Basin Plan includes two discharge prohibitions specifically applicable to logging, construction, and other associated non-point source activities. The prohibitions state:

- The discharge of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature into any stream or watercourse in the basin in quantities deleterious to fish, wildlife, or other beneficial uses is prohibited.
- The placing or disposal of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature at locations where such material could pass into any stream or watercourse in the basin in quantities which could be deleterious to fish, wildlife, or other beneficial uses is prohibited.

Development and implementation of a Total Maximum Daily Load (TMDL) is one means of attaining water quality objectives and protecting beneficial uses in Redwood Creek. The TMDL program is required by Section 303(d)(1)(A) of the Clean Water Act (CWA) that states, "Each State shall identify those waters within its boundaries for which the effluent limitations . . . are not stringent enough to implement any water quality standard applicable to such waters." The same part of the CWA also requires that the State "establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters." Redwood Creek was included on the 1996, and 1998 lists based on the finding that sedimentation is, in part, responsible for the impairment of the cold water fisheries. Section 303(d)(1)(C) of the CWA requires that "Each State shall establish for the waters identified in paragraph (1)(A) of this subsection, and in accordance with the priority ranking, the total maximum daily load..." "As part of California's 1996 and 1998 303(d) list submittals, the North Coast Regional Water Quality Control Board (RWQCB) identified Redwood Creek as water quality limited due to increased sediment loading and designated the watershed as a high priority for TMDL development. The RWQCB began work on the sediment TMDL in 1997, and EPA and the RWQCB worked together to complete the TMDL in 1998" (EPA, 1998). The Regional or State

Board has not adopted an implementation plan for enforcement of the Redwood Creek TMDL written by the RWQCB in 1999.

Table 3: Numeric Targets outlined in the EPA 1998 Redwood Creek TMDL document are as follows:

Parameter	Numeric Targets (Desired Conditions)
Percent fines <0.85mm in riffle crests of fish-bearing streams	<14%
Percent fines <6.5mm in riffle crests of fish-bearing streams	<30%
Percent of stream length in riffles	<25-30% of stream reaches in riffles (reach gradient <2%)
Pool depth in mainstem Redwood Creek reaches with pool-riffle morphology	The mean depth of pools at low flow exceeds 2m
Depths of pools in 3rd and 4th order tributaries with pool-riffle morphology	The mean depth of pools at low flow exceeds 1-1.5m
Median particle size diameter (D_{50}) from riffle crest surfaces	=37mm (single minimum for a reach) =69mm (mean for a reach)
Percent of surface fines <2mm at riffle crests of fish-bearing streams	<20%
Large Woody Debris in any watercourse capable of transporting sediment to a higher order watercourse	Improving trend towards increased large woody debris

The Water Quality assessment of Redwood Creek for the NCWAP 2001 report will discuss the state of the watershed according to comparisons to the following RWQCB water quality objectives and EPA's TMDL numeric targets where data was available.

TABLE 4: CRITERIA USED IN THE ASSESSMENT OF WATER QUALITY DATA

Water Quality Parameter	Range or Threshold	Source of Range or Threshold
pH	6.5-8.5	Basin Plan, p 3-3.00
Dissolved Oxygen	7.0 mg/L	Basin Plan, p 3-3.00
Temperature	No alteration that affects BUs [1]	Basin Plan, p 3-3.00
	No increase above natural > 5 F	Basin Plan, p 3-4.00
	50-60 F MWAT [2] – fully suitable	EMDS Fully Suitable Range [3]
	75 F daily max (lethal)	Cold water fish rearing, RWQCB (2000), p. 37
Specific Conductance	≤ 90% of upper limit at 220umhos	Basin Plan, p 3-6.00
	≤ 50% of upper limit at 145umhos	Basin Plan, p 3-6.00
Nutrients (Biostimulatory Substances)	No increase in concentrations that promote growths and cause nuisance or adversely affect beneficial uses	Basin Plan, p 3-3.00
Percent fines <0.85 mm	<14% in fish-bearing streams [4]	Redwood Creek TMDL, EPA (1998)
Percent fines <6.5 mm	<30% in fish-bearing streams	Redwood Creek TMDL, EPA (1998)

[1] BUs = Basin Plan beneficial uses

[2] MWAT= maximum average weekly temperature, to be compared to a 7-day moving average of daily average temperature

[3] EMDS = Ecological Management Decision Support model used as a tool in the fisheries limiting factors analysis. These ranges and thresholds were derived from the literature and agreed upon by a panel of NCWAP experts.

[4] fish-bearing streams = streams with cold water fish species

Data Quality and Limitations

The data we compared to these ranges and thresholds from a water quality perspective were:

- Continuous water temperature data from data loggers
- Percent fines <0.85, <2 and <6.5 mm from McNeil core samples
- Dissolved oxygen, pH, conductance (dissolved solids), nutrients (nitrogen, phosphorus)

The data and summary plots are included in the Attachments.

Data was not available for comparison of water quality objectives and TMDL targets for the following parameters:

- Water quality objectives: color, tastes and odors, floating material, suspended material, settleable material, oil and grease, biostimulatory substances, sediment load, toxicity, pesticides, chemical constituents, radioactivity, turbidity, bacteria, and total dissolved solids.
- TMDL targets for Redwood Creek: percent of stream length in riffles, pool depth, depths of pools in 3rd and 4th order tributaries, D_{50}, V*, and large woody debris.

A water quality assessment of all parameters potentially impacting the beneficial uses of waters of the north coast is not complete without existing data for comparison purposes. The Department of Fish and Game analyzed the presence of pools, riffles and large woody debris in their report of the status of fish habitat. The RNSP has been sampling for particle size using the Wolman pebble counting method since 1979. Unfortunately, due to calculation errors their D_{50} data from 13 sites cannot be included in this year's assessment. Due to lack of data, this assessment may not reside as the most accurate picture of the status of water quality in Redwood Creek. This assessment is based on information available at the time and is expected to change as new data and analyses become available.

We evaluated existing data for quality with respect to the assessment, and new data collections were at a level to ensure utility in the assessment. Water temperature and stream channel measurements provided by the RNSP were collected with acceptable methods and quality assurance and control for use in the assessment. This also was the case with the water quality data both gathered in the past and more recently in 2001. The primary limitations to the data we evaluated were related to matters of scale—that is, the representativeness of a measurement in a specific location with respect to characterizing a subwatershed. In that context, the data often determine the coarseness of the assessment as some data are more appropriately applied over a larger area than others.

Although there is controversy regarding the utility of streambed substrate data, pebble counts and core samples can provide a perspective on the composition and dynamics of the streambed. Conditions in a riffle may vary considerably, requiring large sample sizes to describe the conditions for salmonids. However, the pebble count and core sample results for the Redwood Creek watershed are useful in providing an idea of streambed conditions and to add validity to other observations, such as the embeddedness and dominant particle sizes data from habitat surveys.

Currently, research is taking place to determine effects of turbidity and suspended sediment on salmonid growth and survival that will be useful in future assessments of sediment impairment and sediment sources. This assessment did not evaluate the status of suspended sediments and turbidity regimes in the watershed, therefore, we can not assess the impacts, if any, of suspended sediment and turbidity on salmonid species. Redwood National and State Parks, in cooperation with USGS, has been monitoring sediment and stream flow throughout the watershed for the past 20 years (RNSP 1997). Suspended sediment and sediment load calculations are presented in the Redwood Creek Watershed Sediment Analysis Update 1999 (RNSP 1999) and are included in Table 5. We recommend that turbidity and suspended sediment rating curves be developed so as to enable a more accurate assessment of water quality and salmonid health in the Redwood Creek Basin.

- **REDWOOD CREEK WATERSHED DISCHARGE PERMITS AND GRANTS**

The North Coast RWQCB administers federal and state permits for work in and out of the channel that could potentially harm water quality. There are no current waste discharge permits issued in Redwood Creek. There is one general NPDES permit in the basin for the Simpson Orick sawmill near Prairie Creek. Under conditions of the permit, annual storm water reports with sampling results are submitted to the Water Board and our staff performs annual inspections of the treatment facilities. The Water Board also administers federally funded grants for watershed restoration programs. Currently, there are no federally funded 319(h) or 205(j) grants in the Redwood Creek basin.

- **STREAM FLOW AND WATER DIVERSIONS**

Please refer to the Department of Water Resources appendix to the Redwood Creek NCWAP 2001 Synthesis Report for flow and water diversion information.

- **WATER COLUMN CHEMISTRY**

The early establishment of Redwood Creek as a National Park resulted in monitoring data for the last 30 years by USGS, RNSP and others. Data for the site at Orick is particularly rich and retrievable through the US Environmental Protection Agency StoRet database (USEPA 2001). Water quality data for over 40 sites, including many tributaries, are available from the USGS water quality website (USGS 2001). The majority of these samples were taken on a quarterly basis by a grab sample method. Woods (1975) sampled surface and intragravel dissolved oxygen in 1974 (Table 6). Anderson (1988) sampled for dissolved oxygen, pH, conductance and alkalinity in 1982 (Table 6). The Surface Water Ambient Monitoring Program (SWAMP) administered by the North Coast Regional Water Quality Control Board collected three samples during 2001 near the town of Orick. SWAMP samples were analyzed for DO, pH, conductivity, temperature, turbidity, alkalinity, ammonia, nitrogen, phosphorus and total dissolved solids (Table 6).

The RWQCB is charged with examining and enforcing all permits for herbicide application. Application of herbicides via ground and aerial methods are known to occur in the upper and middle sub-basins of the watershed. Water quality monitoring does take place but whether there are sampling data for these chemicals in the water is unknown at this time.

Applicable Basin Plan water quality objectives for Redwood Creek are: (1) dissolved oxygen minimum of 8mg/L; (2) specific conductance 90th percentile less than 220umhos and 50th

percentile (median) less than 125umhos, and (3) pH between 6.5 and 8.5. Also, see pages 7-10 for more detailed explanation of these water quality objectives.

See Map 3 for a map of monitoring locations for all sources.

- **WATER TEMPERATURE**

Redwood Creek is unique because it has been closely monitored for temperature since the late 1970's. Woods (1975) presented temperature data recorded in 1974 with a continuous monitoring device for three tributaries. Spot grab sample temperature data from the early 1960's are available from USGS and StoRet for various sites throughout the watershed, however these data are not included in this assessment because spot temperature measurements cannot be used to create trends or characterize temperature of the water at any spatial scale. The USGS and StoRet data are not useful to examine short-term exposure limit exceedences because peak temperatures were not recorded. However, the data set was analyzed by the RNSP in Ozaki et al (1999) for peak temperatures on the mainstem upstream of Lupton Creek. Anderson (1988) presents spot peak temperature data recorded in 1980-81 at 40 locations in the upper, middle and lower watershed. A continuous monitoring device was not used in Anderson's study, but the information is still useful for examination of short-term exposure impacts. Continuous temperature monitoring by the Redwood National and State Parks within park boundaries began in 1992 with more intensive monitoring extending upstream of the park occurring after 1997 (Ozaki et al 1999). Data quality before continuous monitoring began is less reliable because of inconsistencies related to sampling location, depth, time of day, etc. Continuous recording devices and the protocols for deployment have increased the quality and density of information as well as allowing us to calculate a seven-day moving average of daily temperatures and other useful metrics.

In 1998, the Forest Science Project developed a report that compiled temperature monitoring data from 1994-1998 in the Redwood Creek Basin. This report incorporated data from private landowners in addition to RNSP temperature data. With the cooperation of private landowners, the RNSP has monitoring devices deployed at 13 locations within the park and upstream. Raw temperature data was provided from RNSP for use in this assessment. Most of the large landowners also monitor temperature using continuous monitoring devices on their property. This assessment examines data from all these sources in an attempt to characterize the water temperature throughout Redwood Creek.

Raw water temperature data were summarized as the highest of the floating weekly average for the summer, the Maximum Weekly Average Temperature or MWAT. MWATs were calculated from raw temperature data for 1994 to 2001 Maximum MWATs for data collected in Redwood Creek are shown in Table 7 and MWATs are plotted in Figure 1.

Site Name	Creek	Years Sampled	Max MWAT year	Max MWAT
3012	Estuary[5]	1997-98	1997	68
Little Lost Man (10)	Little Lost Man[3]	1974	1974	57
Lost Man (20)	Lost Man[3]	1974	1974	64
Lmc (20)	Lost Man[1]	2001	2001	58
Ldc (30)	Larry Dam Creek[1]	2000, 01	2000	57
3015	Prairie Creek[5]	1997	1997	57
3016, prw	Prairie Creek at Wolf Bridge[5, 1]	1997-99, 2001	1997	60
3013, RwLow	*RedCrk upstm Prairie Creek[5, 1]	1997-99, 2001	1997	67
Tmcd (40)	Tom McDonald Creek[1]	2001	2001	58
3014, RwTtg	*RedCrk upstm Tom McD Crk[5, 1]	1997-99, 2001	1998	70
3002, Bri	Bridge Creek[5, 1]	1996-2001	1999	61
824	Coyote Creek[5]	1994	1994	61
984, Panther	Panther mouth[5, 1]	1974, 1998	1974	66
2019	Upper Panther Creek[5]	1994-95	1995	57
3004, Lac	Lacks Creek[5, 1]	1997-2001	1997	67
1144	Upper Lacks Creek[5]	1998	1998	61
3011	*RedCrk upstm Lacks Creek[5]	1997-98	1998	72
1118	Beaver Creek[5]	1997-98	1998	62
1119, Mill	Mill Creek[5, 1]	1997-98, 2001	1998	61
1120	Molasses Creek[5]	1997-98	1998	63
1121	Moon Creek[5]	1998	1998	68
3006, 1145, Min	Minor Creek[5, 1]	1997-98, 2001	1998	65
1123	Minor Creek Trib[5]	1998	1998	59
1124	Upper Minor Creek[5]	1997-98	1998	61
1125	Sweathouse Creek[5]	1998	1998	62
957	Lupton Creek[5]	1997-98	1998	59
3008, RwOkn	*O'Kane gaging station RedCrk upstm Lupton Creek[5, 1]	1997-99,2001	1998	71
608	High Prairie Creek[5]	1998	1998	56
614	Upper High Prairie Creek[5]	1998	1998	56
3007	*RedCrk upstm Minon Creek[5]	1997-99	1998	65
611	Minon Creek mainstem[5]	1998	1998	62
612	Upper Minon trib[5]	1998	1998	54
613	Upper Minon Creek[5]	1998	1998	54
5041901	Lake Prairie Creek[6]	1996-99	1998	60
5043201	Pardee Creek[6]	1996-99	1996	58

Table 7: Maximum MWATs for all stations in the Redwood Creek Basin from 1974-2001.
Data sources: [1]RNSP (2001), [3]Woods (1975), [5]Lewis,T., et al (2000), [6]Simpson (2000)
*** are locations on mainstem Redwood Creek**
(#) correspond to locations in the MWAT chart, Figure 1

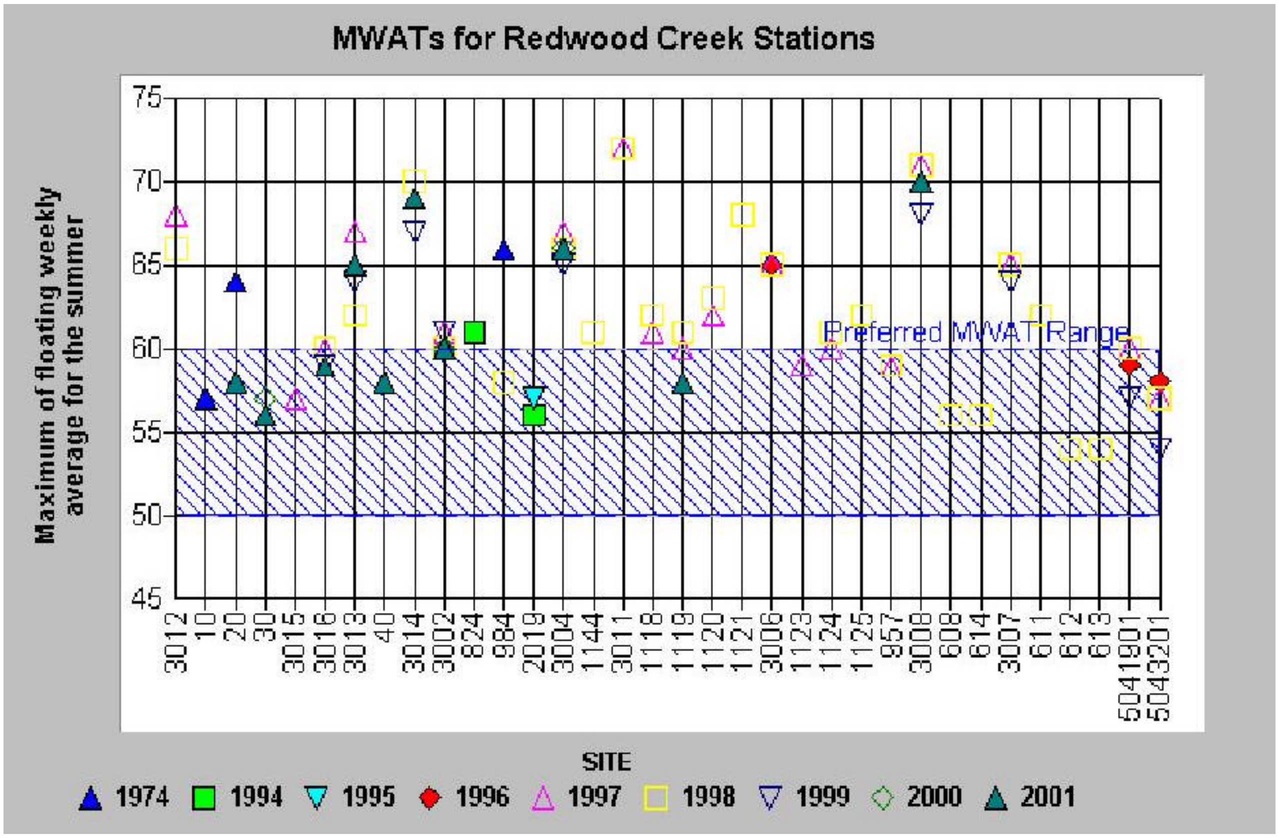

Figure 1: MWAT Temperatures for all stations in Redwood Creek from 1974 to 2001. Data Sources: RNSP (2001), Lewis, et al. (2000), Simpson (2000). See Table 7 for station locations.

Peak temperature data speak to the threat of harm from temporary or short-term exposure to extreme conditions. It is generally accepted that a threshold temperature exists that fish can withstand for short consecutive period of hours before damage is caused by stress (Armour 1991). The following are peak temperatures taken at various locations from different sources. Temperature data from 1974 in Woods (1975) lists three tributaries with MWATs ranging from 57-66F Grab sample data collected from the O'Kane USGS gaging station from 1974-76 showed peak temperatures on the mainstem between 87 and 92F (Ozaki et al 1999). Anderson (1988) noted in 1980 and 1981 that peak temperatures in the entire basin were between 59 and 75F (Figure 2). The RNSP, from 1994 to 1998, noted that during the summer months, tributary temperatures tended to be cooler than the mainstem Redwood Creek (Ozaki, et al 1999). Peak temperatures recorded in tributaries ranged from 63-72F and peak temperatures in the mainstem ranged from 68-81F from 1994-1998 (Ozaki et al 1999).

Redwood National and State Parks submitted raw temperature data for 1999 to 2001for use in this year's assessment. Problems were found in data from the 1999 sites upstream of Lacks and Minon creeks and at Minor Creek as well as upstream of Lacks Creek and at the estuary in 2001. Short-term but large temperature swings were observed that are inconsistent with the rest of the data. We are not incorporating these data for the assessment at this point. These data are plotted in Figures 3-14 with the following hypotheses as to why the data are suspect (exact details are described in Table 8) provided here:

1. There were discharges of hot water from upstream, perhaps due to short events of low water.
2. There was a large or ongoing withdrawal of water from a cold tributary that would normally suppress the water temperature.
3. Regular spikes may be due to poor placement of the Hobos, etc.
4. The estuary site could be influenced by tidal fluctuations and maybe a cold water "wedge". Or it could be related to breaching of the mouth allowing colder ocean waters to mix in the estuary.

See Map 2 for a map of monitoring locations for all sources.

- **IN-CHANNEL SEDIMENT**

Redwood National and State Parks (RNSP) and the USGS Western Ecological Research Center have been sampling in-channel sediment since 1979. Collection methods include sediment core sampling to determine the percentage of fine material in the stream, pebble count sampling for particle size information and monitoring of channel morphology changes at 51 cross sections throughout the basin.

Since 1996, Redwood Creek has been listed by the State Water Resources Control Board as being impaired by excessive sediment, and a TMDL for sediment was completed by the U.S. Environmental Protection Agency in 1998.

The RNSP has closely monitored changes in channel morphology by taking cross-section profiles annually since 1973. Channel width, streambed elevation, thalweg position, and channel fill and scour have been plotted against previous years and analyzed in Varnum and Ozaki (1986), Madej and Ozaki (1996) and the data has been analyzed by many other researchers whose reports can be found via the RNSP website. Discussion of this data is not included in this water quality assessment because the Department of Conservation-Division of Mines and Geology is examining the information from a geomorphological perspective. Their findings will be included in the Division of Mines and Geology appendix to the Redwood Creek NCWAP 2001 Synthesis Report.

There is controversy regarding the utility of streambed substrate data because conditions in a riffle may vary considerably, requiring large sample sizes to describe the conditions for salmonids. However, pebble counts and core samples can provide a perspective on the composition and dynamics of the streambed and add validity to other observations, such as the embeddedness and dominant particle sizes data from habitat surveys. Redwood Creek TMDL includes targets for percent fines of less than 14% of fines < 0.85mm and less than 30% of fines <6.5mm.

As described in the NCRWQCB technical TMDL for Redwood Creek (RWQCB, 1998), the percent of fine material <0.85mm in the channel are known to impact salmonids during the incubation stage. Once the eggs are laid and fertilized, the spawners cover the redds with material from upstream, including clean gravels and cobbles. The interstitial spaces between the particles allow for water to flow into the interior cavity where dissolved oxygen, needed by the growing embryos, is replenished. Similarly, the interstitial spaces allow water to flow out of the interior cavity carrying away metabolic wastes. However, fine particles either delivered to the stream or mobilized by storm flow can intrude into those interstitial spaces, blocking the flow of oxygen into the redd and the metabolic wastes out of it. The reduced permeability into and out of the redd results in a reduction in the rate of embryo survival. The target of <14% fines <0.85mm is generally supported by literature sources as a level that is reasonably protective, recognizing the fact that spatial and temporal variability does exist around that value.

As described in the NCRWQCB technical TMDL for Redwood Creek (RWQCB, 1998), the percent of fine material <6.5 mm in the channel are known to impact salmonids during the emergence stage. After 4 to 6 weeks, the embryos are ready to emerge from the gravel as fry (young swimming fish). The presence of fine sediment in the gravel interstices can impede fry emergence. However, the size of fine particles likely to fill the interstices of redds sufficient to block passage of fry are larger than those likely to suffocate embryos. That is, particles ranging from 0.85 mm to 9.5 mm are capable of blocking fry emergence, depending on the sizes and angularity of the framework particles, while still allowing sufficient water flow through the gravels to support embryo development. Besides a correlation between percent fines and the rate of survival to emergence, there is also a correlation between percent fines and the length of incubation; i.e., the amount of time it takes for the fry to emerge from the egg. Percent fines is also inversely related to the size of emerging fry (Chapman, 1988). Each of these factors impact the ultimate survivability of the embryos and fry. The target of <30% fines <6.5mm is generally supported by literature sources as acceptable for survival to emergence rates and the levels of fines found in unlogged watersheds, recognizing the fact that spatial and temporal variability does exist around that value.

Pebble counts provide a good measure of the surface composition of the streambed. Trends toward smaller sizes indicate influx of fine sediments and either low stream power or transport capability overloaded by small particles (inability to move new sediment through the area). Trends towards larger particles indicate a flushing of smaller particles and sediment transport capability exceeding the influx of new sediment. The Redwood Creek TMDL includes median particle size (D_{50}) targets: a single minimum no less than 37mm and mean of greater than 69mm.

The RNSP has been sampling for particle size using the Wolman pebble counting method since 1979. Unfortunately, due to calculation errors their D_{50} data from 13 sites cannot be included in this year's assessment.

USGS and RNSP conducted sediment core sampling at 10 sites throughout the basin from 1974 to 1995 to identify the percentage of fine sediment present in the channel. Much of the core data from these sources were difficult to analyze due to fractions reported in <1, <4, and <8mm as opposed to the <0.85, < 2, and <6.5mm fractions that have defined target values in the Redwood Creek TMDL. We applied the TMDL targets where data for corresponding targets were available and attempted to evaluate other fractions by deductive reasoning. For example, if a target for fines <6.5mm is <30% and the percentage of fines <4mm was measured as 50%, then the <6.5mm target was exceeded.

The Redwood National and State Parks noted a downward trend in suspended sediment loads at both the Orick and O'Kane gaging stations since 1970 in their Redwood Creek Watershed 1997

Analysis (RNSP 1997). Decreasing suspended sediment in the water column may improve conditions for salmonid production and/or indicate the rate of sediment activity in the watershed.

See attachment Map 1 for a map of sampling locations for all sources.

- **ANALYSIS AND RESULTS BY SUBBASINS**

ESTUARY

Water Column Chemistry

The main monitoring site for water chemistry data in the estuary of Redwood Creek is at the town of Orick, near the upper end of the estuary. Tables 9 show USGS and StoRet data collected for dissolved oxygen, conductivity, pH and some limited nutrients sampled from 1958 until 1988. Thirty years of data indicate a slight increasing trend for DO and pH. These values present conditions that are influenced by tidal fluctuations and ocean inflow to varying degrees (Figures 15-18). There are a few additional monitoring sites closer to the mouth of Redwood Creek in the estuary. The data are scattered and scarce, but can be obtained at the USGS NWISweb website (USGS 2001).

The SWAMP program took three samples at a site near the town of Orick in March-May, 2001, with mean dissolved oxygen of 10.3mg/L (water quality objective >8mg/L), pH at 7.7 (water quality objective 6.5-8.5), and conductance of 105umhos (water quality objective <220umhos). Samples for nitrogen and phosphorus were within normal limits (Table 6). Future sampling efforts from the SWAMP program in addition to historical samples will extend trend lines for pH, dissolved oxygen and conductivity.

Temperature

Water temperatures in the estuary have exceeded the “fully suitable” range for salmonids since at least 1997 when monitoring first began, MWATs being higher than 65F for both years of available data. Currently the estuary is monitored at a site located between the levees, south of the town of Orick. Continuous temperature data show large fluctuations coinciding with times when the sandbar at the mouth of Redwood Creek is breached or perhaps due to interactions with a cold water “wedge” from tidal influences. High temperatures are a concern since this area provides critical habitat for salmonid growth. The mouth of Redwood Creek is very wide and vegetation along the channel consists of grasses and small shrubs that do not shade the channel (Figure 19). Influence from daily fog and cool ocean waters may be the largest factor keeping temperatures cooler but not within the “fully suitable” range for salmonid growth.

Sediment

The only site containing data for in-channel sediment was sampled from the mainstem near the town of Orick by USGS. Redwood Creek at Orick was sampled for percent of fine materials for fractions of <1mm, <4mm and <8mm every two years from 1983 to 1995. However, the TMDL target of <30% for fines <6.5mm was exceeded six out of seven times by the <4mm fraction recorded (Table 10). The data do not fall into TMDL targets classes of <0.85 and <6.5mm as critical to salmonid production. However, data for the lower Redwood Creek sites show that from 1989 to 1991 the TMDL target for the <6.5mm fraction was exceeded. As seen in the upper, middle and lower sub-basins, there is an abundance of coarse, gravel sized material in the streambed. This may represent conditions that should be expected in the depositary area of an estuary.

Redwood Creek Estuary Percent Fines Data								
Stream Name	**Sample Date**	**% Fines <0.85mm**	**% Fines <1mm**	**% Fines <2mm**	**% Fines <4mm**	**% Fines <6.5mm**	**% Fines <8mm**	**n**
TMDL Targets		**<14%**				**<30%**		
RedCrk At Orick[2]	1983		5		**30**		51	3
RedCrk At Orick[2]	1985		1		**47**		69	9
RedCrk At Orick[2]	1989		**21**		**42**		61	14
RedCrk At Orick[2]	1990		**28**		**53**		70	10
RedCrk At Orick[2]	1991		**31**		**45**		61	10
RedCrk At Orick[2]	1992		14		**85**		100	1
RedCrk At Orick[2]	1995		17		**47**		66	5
RedCrk Near Orick[2]	1983		14		29		39	1

Table 10: Percent fines data from McNeil core samplers taken in 1974-1995.
Data sources: [2]USGS (2001) Data in bold exceed TMDL targets.

PRAIRIE CREEK SUB-WATERSHED

Water Column Chemistry

Eight tributary stations in the Prairie Creek sub-watershed were monitored by USGS between 1973 and 1977. Data for dissolved oxygen ranged from 8-13mg/L (water quality objective >8mg/L), pH ranged from 6 to 8.3 (water quality objective 6.5-8.5), and conductivity ranged from 20-130umhos (water quality objective <220umhos) (Figures 20-22). Water quality samples taken in Prairie Creek and its tributaries indicate compliance with Basin Plan objectives and no noticeable trends were observed.

Temperature

The Prairie Creek sub-watershed is greatly influenced by coastal fog and has dense canopy cover, both functioning to moderate water temperatures. This tributary to Redwood Creek hosts a large population of the old redwoods which provide streamside cover over the channel (Figure 19). Existing data show maximum MWATs of 57F at two locations on Prairie Creek from 1997-2001. Three tributaries to Prairie Creek have MWATs around 57F with one recording of 64F in 1974. Unfortunately, the mouth of Prairie Creek is not monitored at the confluence of Redwood Creek. Consequently, how much of an influence this tributary has on cooling the mainstem is unknown. This sub-watershed contains optimal channel shade and climate conditions creating “fully suitable” water temperatures for salmonids.

Sediment

Sediment in Prairie Creek has been monitored at 3 sites since 1974. Much of the existing data consists of suspended sediment and flow. This part of the watershed has not been sampled for particle size (D_{50}) composition. Percent fines data from core samplers for the Prairie Creek watershed consists of two samples at Lost Man Creek from 1974 and three samples at Little Lost Man Creek from 1974 and 1987. The 1974 samples on Lost Man and Little Lost Man Creeks exceeded the TMDL target of less than 14% fines <0.85mm (Table 11). The 1987 Little Lost Man sample of 26% less than 4mm does not fall into the TMDL targets as critical to salmonid production. However, it is close to the 30% TMDL target for < 6.5mm.

Intensive fine and suspended sediment sampling occurred in Prairie Creek during 1988-90 when the California Department of Transportation constructed a highway bypass around and through the watershed and for ten years after construction was completed. These data are not included in this assessment due to the specific nature of the sampling. Most of the monitoring from this incident developed from a violated water quality permit and was not a long-term sampling project to monitor and assess the health of Prairie Creek. Data collected under permit requirements showed that impacts to salmonid habitat did occur and Prairie Creek may still be coping with the affects of the construction. Presently, the RNSP and CalTrans monitor lasting impacts to Prairie Creek. Detailed information about the Prairie Creek Highway 101 bypass can be found in Klein (1993), Coey (1998), Roelofs (1999), Welsh (1999) and many others.

Prairie Creek Percent Fines Data

Stream Name	Sample Date	% Fines <0.85mm	% Fines <1mm	% Fines <2mm	% Fines <4mm	% Fines <6.5mm	% Fines <8mm	n
TMDL Targets		<14%				<30%		
Little Lost Man[3]	1974	**18**						10
Little Lost Man[1]	1987		10		26		32	1
Lost Man[3]	1974	**26**						5

Table 11: Percent fines data from McNeil core samplers taken in 1974-1995.

Data sources: [1]RNSP (2001) and [3]Woods (1975). Data in bold exceed TMDL targets.

LOWER REDWOOD CREEK

Water Column Chemistry

USGS monitored 26 sites in the lower Redwood Creek basin between 1970 and 1980. Most of the sites were sampled from 1974-1975. Three sites are along the mainstem and 23 sites are on tributaries. Data for dissolved oxygen ranged from 7-13mg/L (water quality objective <8mg/L), pH ranged from 5.5 to 8.5 (water quality objective 6.5-8.5), and conductivity ranged from 25-250umhos (water quality objective <220umhos) (Figures 23-25). Samples from the lower watershed area show compliance with Basin Plan water quality objectives and no noticeable trends were observed.

Temperature

Temperature data for lower Redwood Creek were collected at four locations, two along the mainstem and two at tributaries. Maximum weekly average temperatures for Bridge Creek have steadily resided around 60F from 1996 to 2001. This consistent MWAT is may be a result of canopy and channel protection offered by the RNSP. Although MWAT temperatures are steady, they just fall within the “fully suitable” range for salmonid protection. After leaving Redwood Valley in the middle sub-basin, the mainstem is not monitored until Tom McDonald Creek, 15 miles downstream. However we noticed that MWAT temperature on the mainstem averages 70F at Tom McDonald Creek and that warm 72F water flowing from the middle sub-basin is cooled about 2 degrees when it reaches Tom McDonald Creek. Redwood Creek flows through patches of giant trees along the channel in this part of the sub-basin that may provide enough shade to lower temperatures even further. Fog influence begins to take effect just before the confluence with Prairie Creek, decreasing air temperatures and further cooling the stream. Shade covering the channel, fog and, to an unknown extent springs and underflow, may help to reduce temperatures from 70F at the Tall Trees Grove to 67F upstream of the confluence with Prairie Creek just before flowing into the estuary (maximum MWATs for 1997-2001) (Figure 26).

Janda (1975) states that summer maximum water temperatures in the lower basin are decreased because of taller and more abundant riparian vegetation and summer fog that prevents sunlight from reaching the water surface. Maximum MWATs are slightly cooler in the lower sub-basin than in the middle sub-basin, but temperature data from the past four years exceed the "fully suitable" range even with contributions from cold water tributaries and fog influence. Temperature in this sub-basin may be controlled by the NW/SE aspect of the basin, rather than riparian vegetation, cold water flow and climate.

Sediment

The lower sub-basin of Redwood Creek was sampled 14 times at 7 sites to determine the amount of fine materials present in the channel. Sites at McArthur and Harry Weir Creeks, the mainstem up and downstream of Tall Trees Grove, and upstream of the confluence with Prairie Creek were each sampled for fine sediment using core samplers in 1979 and 1994 by the RNSP. Redwood Creek upstream of Harry Weir Creek and Redwood Creek near Miller Creek was sampled in 1983 by USGS (Table 12). McArthur, Harry Weir and the Tall Trees Groves sites were sieved at <8mm once in 1979 and again in 1994. Three core samples were taken from Redwood Creek upstream of Harry Weir Creek and sieved for fractions of fine sediment <1mm, <4mm and <8mm in 1983.

Not all the data presented here fall into TMDL targets classes as critical to salmonid production. However, data for lower Redwood Creek sites show that samples for the <4mm fraction of fine sediment exceeded the <6.5mm TMDL target. As seen in the Upper and Middle Redwood Creek sub-basins, there is an abundance of coarse, gravel sized material in the streambed.

According to the geomorphology examination conducted by the Division of Mines and Geology, the channel in this area is wide with a low gradient and contains terraces and large gravel bars. Their findings may help to explain the presence of large materials in the channel. See the Department of Conservation, Division of Mines and Geology fluvial geomorphology section of the appendix report to the Redwood Creek NCWAP 2001 Synthesis Report.

Lower Redwood Creek Percent Fines Data

Stream Name	Sample Date	% Fines <0.85mm	% Fines <1mm	% Fines <2mm	% Fines <4mm	% Fines <6.5mm	% Fines <8mm	n
TMDL Targets		<14%				<30%		
RedCrk upstm Prairie[1]	1979			20			32	
RedCrk upstm Prairie[1]	1994			15			33	
McArthur[1]	1979			14			49	
McArthur[1]	1994			12			36	
Tall Trees Grove[1]	1979			3			26	
Tall Trees Grove[1]	1994			6			16	
Tall Trees Grove[1]	1979			9			47	
Tall Trees Grove[1]	1994			22			41	
Harry Weir[1]	1979			4			40	
Harry Weir[1]	1994			28			40	
RedCrk upstm Harry Weir[2]	1983		14		**36**		46	3

Table 12: Percent fines data from McNeil core samplers taken in 1974-1995. Data sources: [1]RNSP (2001), [2]USGS (2001) Data in bold exceed TMDL targets.

MIDDLE REDWOOD CREEK

Water Column Chemistry

USGS monitored water quality at four sites in the middle sub-basin from 1973 to 1977. Three sites are on mainstem Redwood Creek and two are tributary sites on Highslope and Lacks Creeks. Data for dissolved oxygen ranged from 8-12mg/L (water quality objective <8mg/L), pH ranged from 6.5-8.5 (water quality objective 6.5-8.5), and conductivity ranged from 40-260umhos (water quality objective <220umhos) (Figures 27-29). Data from the middle sub-basin are in compliance with Basin Plan water quality objectives and no noticeable trends were observed.

Temperature

The RNSP and landowners closely monitor this area to prevent damage to the parkland downstream. Middle Redwood Creek is the most intensely monitored area of the watershed and temperature data has been collected in this sub-basin since 1996. Tributaries are borderline or exceed the “fully suitable” range, while the mainstem approaches the lethal limit of 75F. Salmonid habitat may be threatened by temperature in this sub-basin by lack of streamside trees which function to create a cooling microclimate, perhaps a wide channel, and is influenced only slightly by cold water from tributaries to the mainstem.

The east side of the mainstem in this sub-basin is bordered by saplings and grasslands offering little cover. Small to medium trees with patches of saplings and grassland border the west side of Redwood Creek in this sub-basin (Figure 30). Lack of canopy cover along the mainstem and perhaps a widened channel [more fluvial geomorphology information needed from DMG] may contribute to increased temperatures, especially at Redwood Valley, upstream of Lacks Creek, where maximum MWATs are as high as 72F.

The mainstem is monitored at one site in this sub-basin, upstream from Lacks Creek. Temperature monitored on 10 tributaries located on Lupton, Sweathouse, Minor, Moon, Molasses, Mill, Beaver, Lacks, Panther and Coyote Creeks. Monitoring on upper Minor and upper Lack Creeks, two of the major tributaries in the watershed, show cooler (61F) water flowing into mainstem Redwood Creek. Water flowing downstream from the O'Kane station increases from 71 to 72F (maximum MWATs from 1997-2001) at the mainstem Lacks Creek site, both sites being higher than the "fully suitable" range. Tributaries upstream of the mainstem site at Lacks Creek show maximum MWATs of 59-68F water flowing into the middle mainstem. Water from tributaries is up to 12 degrees F cooler, yet the mainstem increases one degree as it flows past those tributaries. Tributaries downstream from the mainstem Lacks Creek site contribute water in the 57-66F range (maximum MWATs from 1974, 1994-2000). Tributaries may not decrease mainstem temperatures much through the middle portion of the basin. Here water quantity may be among the many factors required for maintaining cold water temperatures on the mainstem though comparisons with flow data have not been performed. Climate and canopy cover, as well sunlight impacts from the basin's NW/SE aspect, may also pose threats to temperature regimes in the middle sub-basin.

Sediment

The mainstem in the middle sub-basin of Redwood Creek was sampled with McNeil core samplers upstream of Panther Creek in 1983 and in 1987 and three tributaries, Panther, Lacks and Molasses Creeks, were sampled with cores at various times between 1974 and 1994. See Table 4 for the data from these sampling events.

Panther Creek was sampled for fine sediment using core samplers in 1974, 1979, 1987, 1990 and 1994 with size fractions reported at <0.85, <1, <2, <4 and <8mm. The percent of fine sediment at Panther Creek exceeded the TMDL targets of <14% for the <0.85mm fraction and the <4mm fraction exceeded the <30% target for the <6.5mm fraction. The mainstem site upstream from Panther Creek shows the <4mm fraction exceeded the <30% target for <6.5mm in 1983 and 1987. The Panther Creek area seems to be a problem spot in terms of spawning substrate required for salmonids, recognizing that the data is scattered and scarce. Lacks Creek was sampled in 1987 with results showing compliance with TMDL targets. The abundance of material <4mm, as seen in Panther Creek, threatens salmonid fry emergence. Smaller particles can smother salmonid embryos, especially those 6.5mm and less in diameter (Bjornn, et al 1977). It is difficult to comment on the data falling into fractions not incorporated into TMDL targets. However, our attempted comparison of the data shows that there is an abundance of gravel sized material present in this sub-basin.

Middle Redwood Creek Percent Fines Data								
Stream Name	**Sample Date**	**% Fines <0.85mm**	**% Fines <1mm**	**% Fines <2mm**	**% Fines <4mm**	**% Fines <6.5mm**	**% Fines <8mm**	**n**
TMDL Targets		<14%				<30%		
Panther[3]	1974	**30**						10
Panther[1]	1979			3			24	
Panther[2]	1987		15		**42**		57	1
Panther[2]	1990		21		**50**		62	5
Panther[1]	1994			13			26	
RedCrk upstm Panther[2]	1983		15		**42**		65	2
RedCrk upstm Panther[2]	1987		18		**39**		54	1
Lacks[2]	1987		2		3		6	1
Molasses[1]	1979			14			37	
Molasses[1]	1994			19			29	

Table 13: Percent fines data from McNeil core samplers taken in 1974-1995.
Data sources: [1]RNSP (2001), [2]USGS (2001), and [3]Woods (1975). Data in bold exceed TMDL targets.

UPPER REDWOOD CREEK

Water Column Chemistry

Water chemistry in the upper basin was sampled from 1973-1975 at the USGS O'Kane gaging station at the Highway 299 bridge at the lower end of the sub-basin. Data show that dissolved oxygen ranged from 8-12mg/L (water quality objective <8mg/L), pH data ranged from 7-8.5 (water quality objective 6.5-8.5) and conductance ranged from 50-150umhos (water quality objective <220umhos). This headwaters area provide important information of the base level water quality for the Redwood Creek basin. Impacts to this area may have lasting affects to water quality downstream and throughout the watershed. Although rough terrain and steep channels make sampling difficult, an effort should be made to characterize the water chemical parameters in this area, especially to monitor the potential impacts of land use activities such as herbicide applications. Data from the upper watershed obtained for this assessment show compliance with Basin Plan water quality objectives and no noticeable trends were observed. See data for the O'Kane site named " RedNrBlu" in Figures 27-29.

Temperature

The mainstem in the upper sub-basin has been monitored upstream of Minon Creek and at the O'Kane gaging station upstream of Lupton Creek, 11.5 miles downstream from Minon Creek. Tributaries monitored in the upper sub-basin include Pardee, Lake Prairie, Minon and High Prairie Creeks. Mainstem temperatures are coolest in this sub-basin possibly due to cold water inputs from tributaries and the presence of large trees bordering a narrow incised channel (Figure 31).

MWATs for the mainstem exceed the "fully suitable" range for salmonid production with maximum MWATs of 65F at Minon Creek and 71F at the O'Kane station. However, tributaries in the upper watershed exhibit maximum MWATs of 54-65F. Grasslands cover much of the ridges in this sub-basin of the watershed, but the influence of cold springs might keep temperatures low compared to the rest of the watershed. Although this area is managed by logging activities which threaten canopy cover over the channel, cold water flows from tributaries, and perhaps a cool microclimate created by an incised channel, ensure that mainstem temperatures low in the upper sub-basin.

Sediment

Upper Redwood Creek basin is a major contributor of sediment down the mainstem (Madej, 1991). According to Ozaki (1988) the channel in this sub-basin has widened from increased sediment inputs caused by landsliding events from the 1964 and subsequent storms. Bedrock is exposed in the channel bottom implying that the extraneous sediment has moved downstream, however resultant damage may still impact the channel and thus, spawning habitat.

The site at Hwy 299 was sampled for percent of fine material using McNeil cores in 1979, 1983 and each year from 1989 to 1992 (Table 14). The fractions recorded do not fall into the TMDL targets as critical to salmonid production. However, it appears that gravel sized materials approach TMDL target values, thus posing a threat spawning habitat in the upper sub-basin. The presence of gravel sized material 4mm suggest that fine sediments have moved out of this portion of the watershed. [but would we expect to see more cobble now? DMG, what to you think?]

Upper Redwood Creek Percent Fines Data

Stream Name	Sample Date	% Fines <0.85mm	% Fines <1mm	% Fines <2mm	% Fines <4mm	% Fines <6.5mm	% Fines <8mm	n
TMDL Targets		<14%				<30%		
O'Kane Station[1]	1979			9			13	
RedCrk nr BluLake[2]	1983		9		25		40	2
RedCrk nr BluLake[2]	1989		20		**33**		44	11
RedCrk nr BluLake[2]	1990		17		**39**		56	7
RedCrk nr BluLake[2]	1991		11		25		34	1
RedCrk nr BluLake[2]	1992		12		26		36	10

Table 14: Percent fines data from McNeil core samplers taken in 1974-1995. Data sources: [1]RNP (2001), [2]USGS (2001). Data in bold exceed TMDL targets.

- **WATER COLUMN CHEMISTRY SUMMARY**

Water chemistry data examined suggests that Redwood Creek is a moderately hard water, moderately oligotrophic stream, with adequate water quality to support salmonid populations. Nothing can be concluded about the quality of water from the upper portion of the watershed due to a lack of sampling sites, except that water quality at the first station below the upper sub-basin is good. Dissolved oxygen and pH values do not change much from one sub-basin to another. Conductivity in Prairie Creek was slightly lower in the 1970's compared with the rest of the watershed. Nutrients (nitrogen and phosphorus) are low.

Parameters not compared to water quality objectives due to lack of sufficient data are: color, tastes and odors, floating material, suspended material, settleable material, oil and grease, biostimulatory substances, sediment load, toxicity, pesticides, chemical constituents, radioactivity, turbidity, bacteria, and total dissolved solids. Due to heightened interest in this watershed, we are fortunate to have 30 years of water chemistry data to detect some changes over time.

- **TEMPERATURE SUMMARY**

The mainstem reaches, especially in the middle section of the basin, experience the highest temperatures perhaps due to wide channels with little to no canopy cover and a NW/SE aspect. Throughout the basin, cold water tributaries help to ameliorate increases in, and in some cases, lower mainstem temperatures. Overall, the headwaters area of Redwood Creek and the Prairie Creek sub-watershed are the coolest perhaps due to cold water inputs from tributaries with tall streamside trees and steep inner gorges which provide shading over the channel. Improvements in riparian vegetation and protection of cold water flows can help to reduce water temperatures, recognizing that some channels in the basin may be too wide to support riparian vegetation dense and tall enough to fully shade the channel and that cold water flows from tributaries may be insufficient to impact mainstem temperatures. It is also recognized that shade provided by dense canopy cover over the channel maintains cool water, but does little to lower temperatures.

For such a large watershed with numerous tributaries, the Redwood Creek basin is well monitored for temperature. Some data gaps exist, but overall one can paint a fairly good picture of what summer water temperatures have been like in the last seven years thanks to great monitoring efforts and cooperative landowners.

- **SEDIMENT SUMMARY**

Based on the limited data available, sediment continues to impair water quality and salmonid habitat, due to the small size of channel substrate and its mobility. It appears that finer sediment from past practices is moving through the system in waves, but that the system overall is still overloaded with gravel sized material. Existing data for fines in the <0.85mm meet the TMDL targets of 14%, but fines <6.5mm are above the target of <30%. Smaller particles can smother salmonid embryos, especially those 6.5mm and less in diameter (Bjornn, et al 1977). Small particle sizes may not be desirable for anadromous salmonids, however there is survival of salmonid embryos to emergence as evidenced by the existence of these fish in the watershed. The small particle sizes are more mobile and the opportunity for redd destruction is real in the Redwood Creek watershed. Both may contribute to decreasing populations in conjunction with other limiting factors. Currently, research is taking place to determine effects of turbidity on salmonid growth that, is hoped, will be useful in future assessments of sediment impairment and sediment sources.

- **BIOLOGICAL**

In 1974 Averett and Iwatsubo (1974) did a study of aquatic life present in Redwood Creek. Sites were selected throughout the watershed, focusing on parklands, and sampled for bacteria, algae and macroinvertebrates. See Figure 32 for a map of locations sampled. Their study showed low counts of fecal coliform, inconclusive results from periphyton and phytoplankton counts, and high numbers of collector and predator species of macroinvertebrates. Averett and Iwatsubo concluded that there is an abundance of fine particulate organic mater in the watershed. Future sampling at their sites could be useful for comparison purposes although the technique and identification methods have changed since these studies were done.

Prairie Creek was sampled for macroinvertebrates during the construction of the Highway 101 bypass to determine impacts of fine sediment to macroinvertebrates, and likewise to salmonid populations, in the sub-watershed. Detailed information about the Prairie Creek Highway 101 bypass and the macroinvertebrates sampling performed can be found in Klein (1993), Coey (1998), Roelofs (1999), Welsh (1999) and many others.

- **ISSUES**
  - Mainstem temperatures are threatened by lack of canopy and insufficient cold water inputs from tributaries. Increased tributary flow and stable canopy cover may encourage a cooling effect on the mainstem, recognizing that shade provided by dense canopy cover over the channel maintains cool water, but does little to lower temperatures.
  - Mainstem temperatures are impacted by a widened channel and the NW/SE aspect of the basin, especially in the middle sub-basin, which may cause water temperatures to exceed the “fully suitable” range for salmonids.
  - Basic water chemistry is not a limiting factor, however the extent to which turbidity and suspended solids may affect the salmonid resource has not been explored (consider using a Bill Trush approach?)
  - Small streambed materials may or may not be what is expected in this type of incised highly erodable basin geology type. [need to consult with DMG and their fluvial analysis]
  - Streambed materials are small and may not be preferable for salmonids according to the literature. However, steelhead have been observed along the upper mainstem according to RNSP and Fish and Game data, but to what degree the full potential is not realized due to sediment impacts is unknown.
  - Fall chinook are present up to the RNSP park protection zone in the lower middle sub-basin. Continued decreases in particle sizes will threaten their spawning habitat, as winter flows destroy or cap the redds, and survival to emergence of embryos is impeded by the abundance of small particles.

- **RECOMMENDATIONS**
  - All monitoring locations for sediment are in the mainstem, with the exception of Prairie Creek. Sampling tributaries for particle size and percent of fine sediment will be useful to indicate the condition of spawning habitat available to salmonids. Also, increase in-channel sediment sampling throughout the range of anadromy in order to assess the health of spawning substrates.
  - Promote research to determine affects of turbidity and suspended solids on salmonid health and growth.
  - Protect and foster improvements of cold water flows from tributaries and riparian function of the canopy to maintain and achieve optimal temperatures throughout the basin, perhaps excluding the Prairie Creek sub-watershed and particularly in the lower and middle sub-basins.
  - Increased continuous temperature monitoring at additional sites along the mainstem will improve our understanding of the influence of cold water tributaries on critical migratory passageways for spawning salmonids and/or how much cold water refugia is available. Continuous temperature monitoring should commence at these locations:
    - Upper sub-basin – on the mainstem downstream of Noisy Creek
    - Middle sub-basin - on the mainstem downstream of Minor, Lacks and Panther Creeks
    - Lower sub-basin – on the mainstem up and downstream of Devils Creek, up and downstream of Bridge Creek, and downstream of the Tall Trees Grove.
    - Prairie Creek – on mainstem Prairie Creek just before the confluence with Redwood Creek
  - Continue SWAMP monitoring to provide data for assessing trends over time at the Orick station
  - Conduct macroinvertebrates sampling throughout basin to assess water quality and habitat conditions for salmonids

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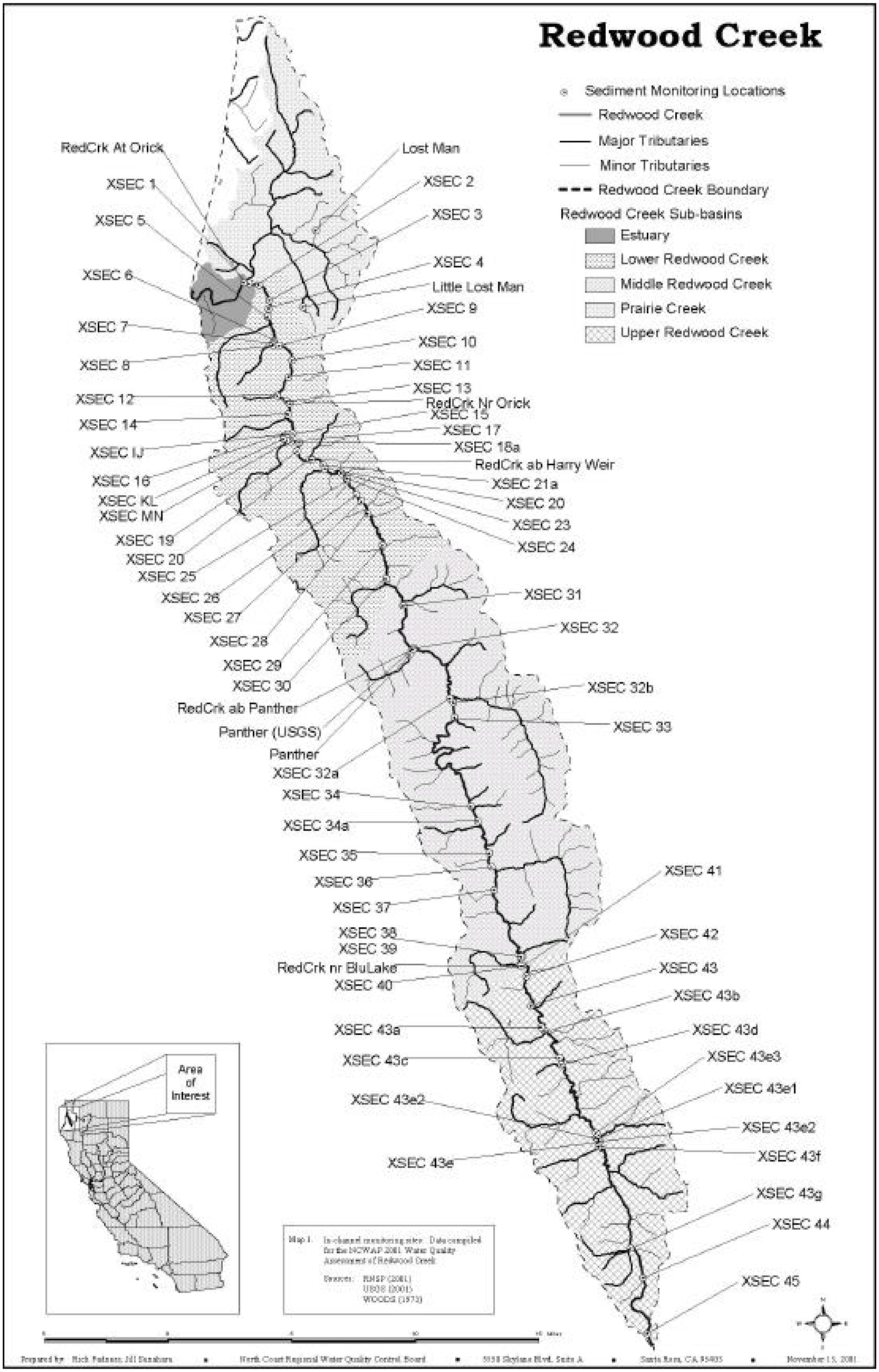
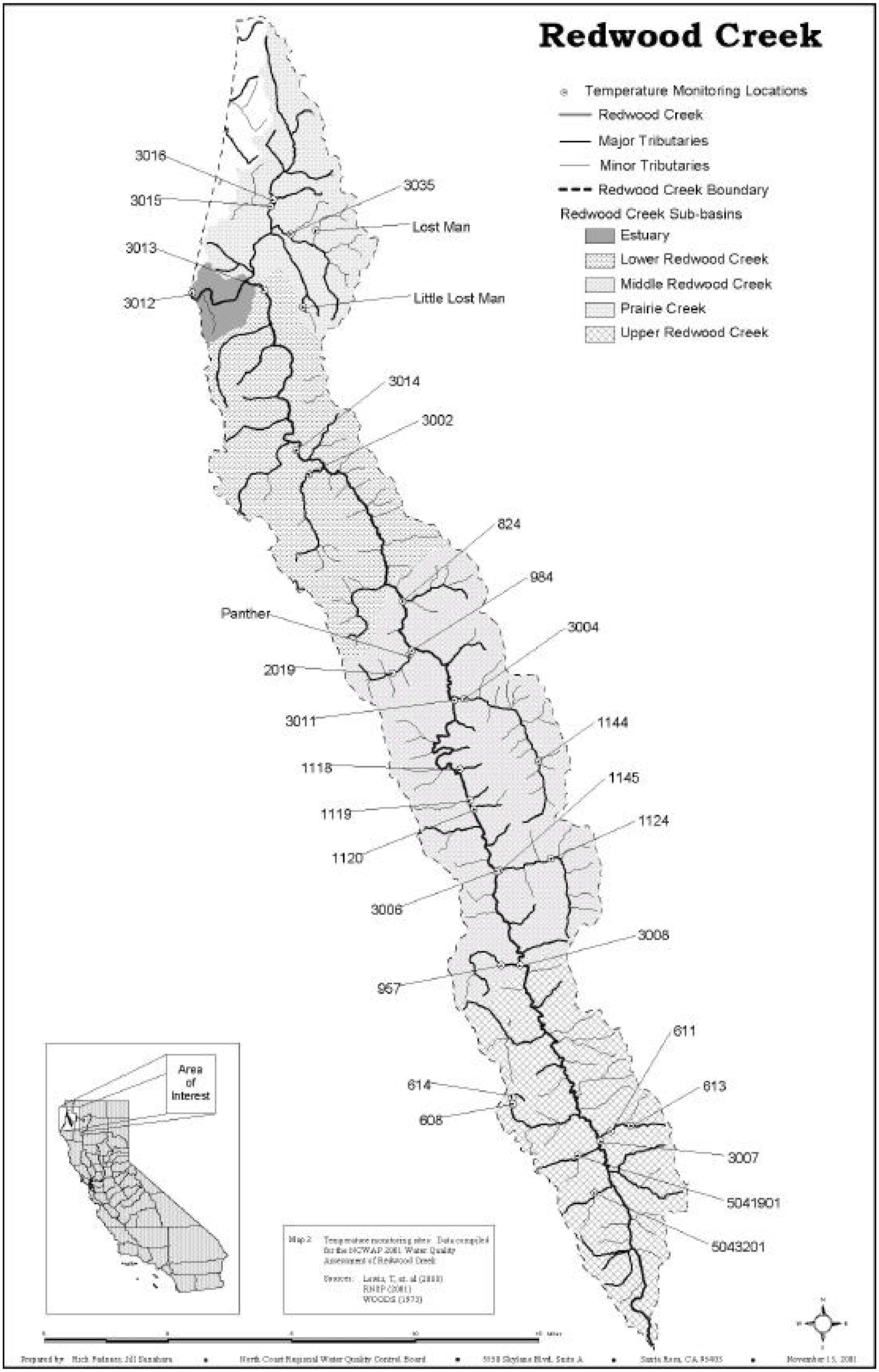
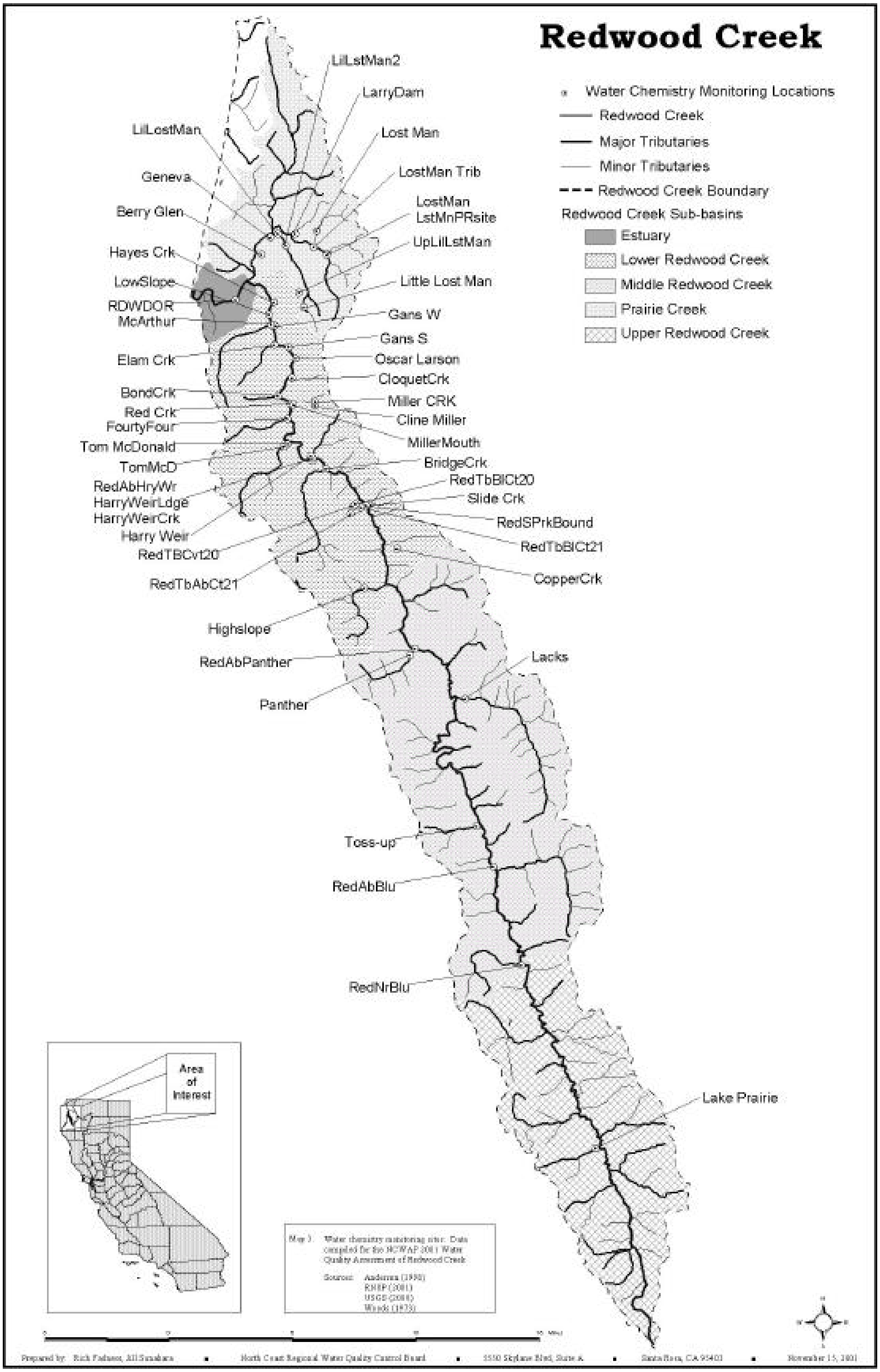
2001
REDWOOD CREEK WATER QUALITY ASSESSMENT

ATTACHMENTS


Redwood Creek
Sediment Monitoring Locations
Redwood Creek
Major Tributaries
Minor Tributaries
Redwood Creek Boundary
Redwood Creek Sub-basins
Estuary
Lower Redwood Creek
Middle Redwood Creek
Prairie Creek
Upper Redwood Creek
RedCrk At Orick
Lost Man
XSEC 1
XSEC 2
XSEC 5
XSEC 3
XSEC 4
XSEC 6
Little Lost Man
XSEC 9
XSEC 7
XSEC 10
XSEC 8
XSEC 11
XSEC 13
XSEC 12
RedCrk Nr Orick
XSEC 15
XSEC 14
XSEC 17
XSEC IJ
XSEC 18a
RedCrk ab Harry Weir
XSEC 16
XSEC 21a
XSEC KL
XSEC 20
XSEC MN
XSEC 23
XSEC 19
XSEC 24
XSEC 20
XSEC 25
XSEC 26
XSEC 31
XSEC 27
XSEC 28
XSEC 32
XSEC 29
XSEC 30
XSEC 32b
RedCrk ab Panther
XSEC 33
Panther (USGS)
Panther
XSEC 32a
XSEC 34
XSEC 34a
XSEC 35
XSEC 36
XSEC 41
XSEC 37
XSEC 38
XSEC 42
XSEC 39
RedCrk nr BluLake
XSEC 43
XSEC 40
XSEC 43b
XSEC 43a
XSEC 43d
XSEC 43c
XSEC 43e3
Area of Interest
XSEC 43e1
XSEC 43e2
XSEC 43e2
XSEC 43f
XSEC 43e
XSEC 43g
XSEC 44
XSEC 45


Redwood Creek
Temperature Monitoring Locations
Redwood Creek
Major Tributaries
Minor Tributaries
Redwood Creek Boundary
Redwood Creek Sub-basins
Estuary
Lower Redwood Creek
Middle Redwood Creek
Prairie Creek
Upper Redwood Creek
3016
3015
3035
Lost Man
3013
3012
Little Lost Man
3014
3002
824
984
Panther
3004
2019
3011
1144
1118
1145
1119
1124
1120
3006
3008
967
611
614
613
608
3007
5041901
5043201
Area of Interest



Redwood Creek
Water Chemistry Monitoring Locations
Redwood Creek
Major Tributaries
Minor Tributaries
Redwood Creek Boundary
Redwood Creek Sub-basins
Estuary
Lower Redwood Creek
Middle Redwood Creek
Prairie Creek
Upper Redwood Creek
LilLstMan2
LarryDam
LilLostMan
Lost Man
Geneva
LostMan Trib
Berry Glen
LostMan
LstMnPRsite
Hayes Crk
UpLilLstMan
LowSlope
Little Lost Man
RDWDOR
McArthur
Gans W
Gans S
Elam Crk
Oscar Larson
CloquetCrk
BondCrk
Miller CRK
Red Crk
Cline Miller
FourtyFour
Tom McDonald
MillerMouth
TomMcD
BridgeCrk
RedAbHryWr
RedTbBlCt20
HarryWeirLdge
Slide Crk
HarryWeirCrk
RedSPrkBound
Harry Weir
RedTBCvt20
RedTbBlCt21
RedTbAbCt21
CopperCrk
Highslope
RedAbPanther
Lacks
Panther
Toss-up
RedAbBlu
RedNrBlu
Lake Prairie
Area of Interest
Map 3. Water chemistry monitoring sites: Data compiled for the NCWAP 2001 Water Quality Assessment of Redwood Creek
Sources:
North Coast Regional Water Quality Control Board
5550 Skylane Blvd, Suite A
Santa Rosa, CA 95403
November 15, 2001

STATION	DATE	Sample Time	DO (mg/L)	Solubility (mg/L)	DO (%Sat)	pH	SC (umhos)	WATER TEMP (C)	AIR TEMP (C)	TURB (NTU)	ALK (mg/L CaCO3)	AMMONIA NITROGEN (mg/L N)	NITRATE (mg/L N)	NITRITE (mg/L N)	TKN (mg/L N)	TOTAL Phosphate Phosphorus (mg/L P)	TDS (mg/L)
[8]SWAMP																	
Orick	3/21/2001	1700	10.2	10.3	99.0	7.84	103	14	16.5		37	nd	0.13	nd	nd	nd	59
Orick	4/25/2001	1115	10.3	10.7	96.1	7.73	106	12.5	17.5	0.6	39	nd	0.1	nd	nd	0.091	64
Orick	5/16/2001	1000	10.4	10.7	97.6	7.65	102	12.6	22.5	1.7	36	nd	0.17	nd	nd	0.05	72
[3]Woods Thesis																	
							Explanation										
Little Lost Man	6/26-11/22/74		9.88		93.8		Mean surface water DO										
Little Lost Man	6/26-11/22/74		9.64		91.7		Mean intragravel DO										
Lost Man	6/26-11/22/74		10.31		99.5		Mean surface water DO										
Lost Man	6/26-11/22/74		6.56		62.5		Mean intragravel DO										
Panther	6/26-11/22/74		10.81		104.1		Mean surface water DO										
Panther	6/26-11/22/74		8.39		80		Mean intragravel DO										
[7]Anderson Thesis																	
Prairie	8/13-21/81		10.3		94	6.7	91	10.5			24						
Wolf			10.3-10.6		94-101	6.8	98	11.0-13.0			16						
L. Lost Man			10.2-10.3		96-98	7	77-91	10.5-13.0			22						
Tom McDonald			9.8-10.2		95-97	6.8	64	12.0-15.5			16						
Emerald			10.2		98	7	114	12.5-13.0			41						
Panther						7	70-79	10.0-15.0			24						
Lacks			9.0-9.5		101-110		193	17.0-23.0									
Tossup			9.4-10.4		94-100		130	12.0-14.5									
Mill			9.1-9.8		94-98		165	13.0-15.5									
Lake Prairie			9.8-10.0		98-102	6.6	65-95	11.0-14.0			23						
Minon			7.4-9.0		76-98	7.3	221-252	13.0-17.0			89						
Redwood			7.7-9.4		88-103	7.1	189-209	15.0-20.0			62						

Table 6: Compilation of water chemistry data from [8]SWAMP (2001), [3]Woods (1975) and [7]Anderson (1988)

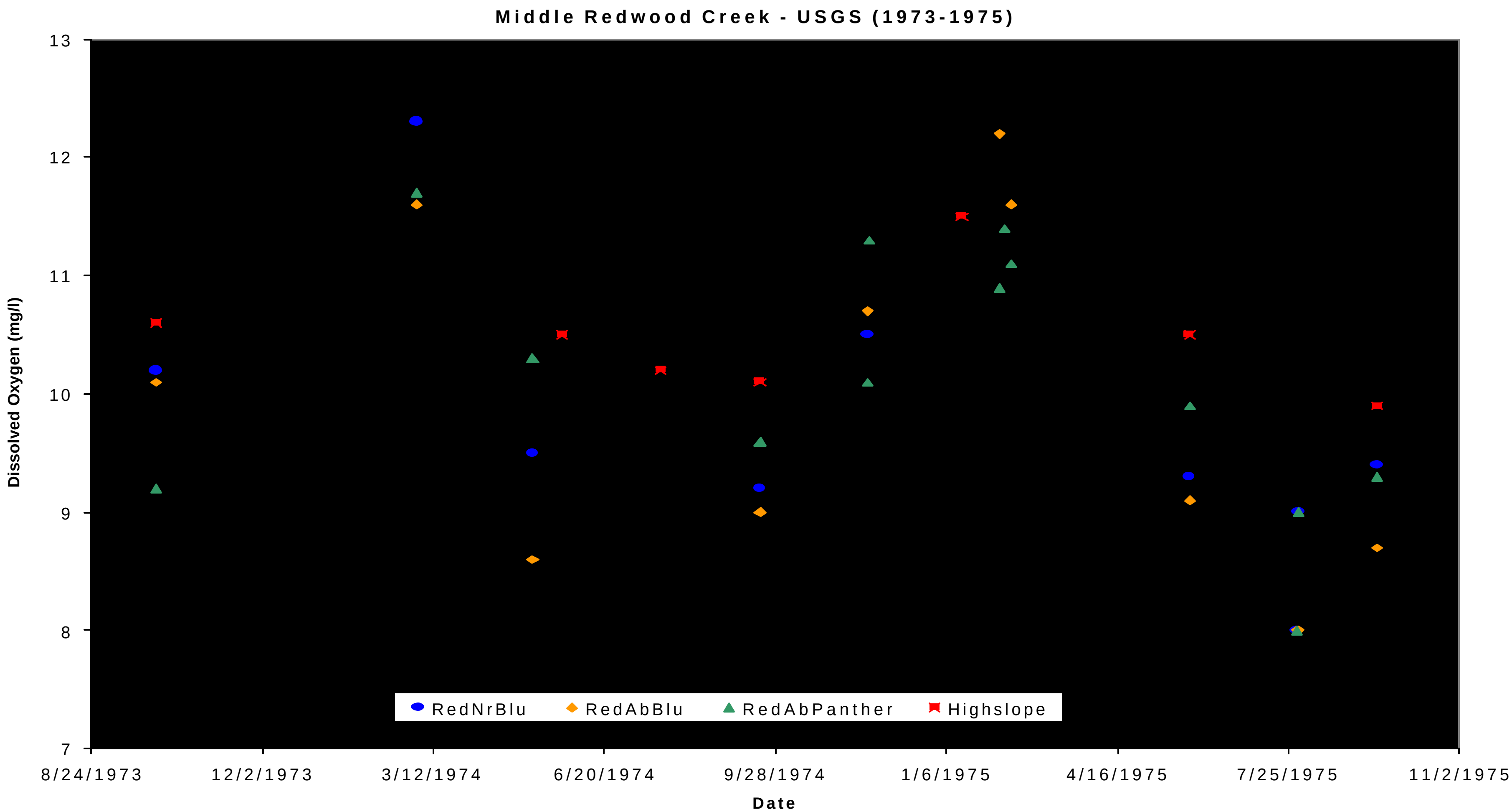


Figure 27: USGS data for dissolved oxygen for the period of record 1973-1977 for Middle Redwood Creek (incorporates O'kane/RedNrBlu station). Data source: [2]USGS (2001)

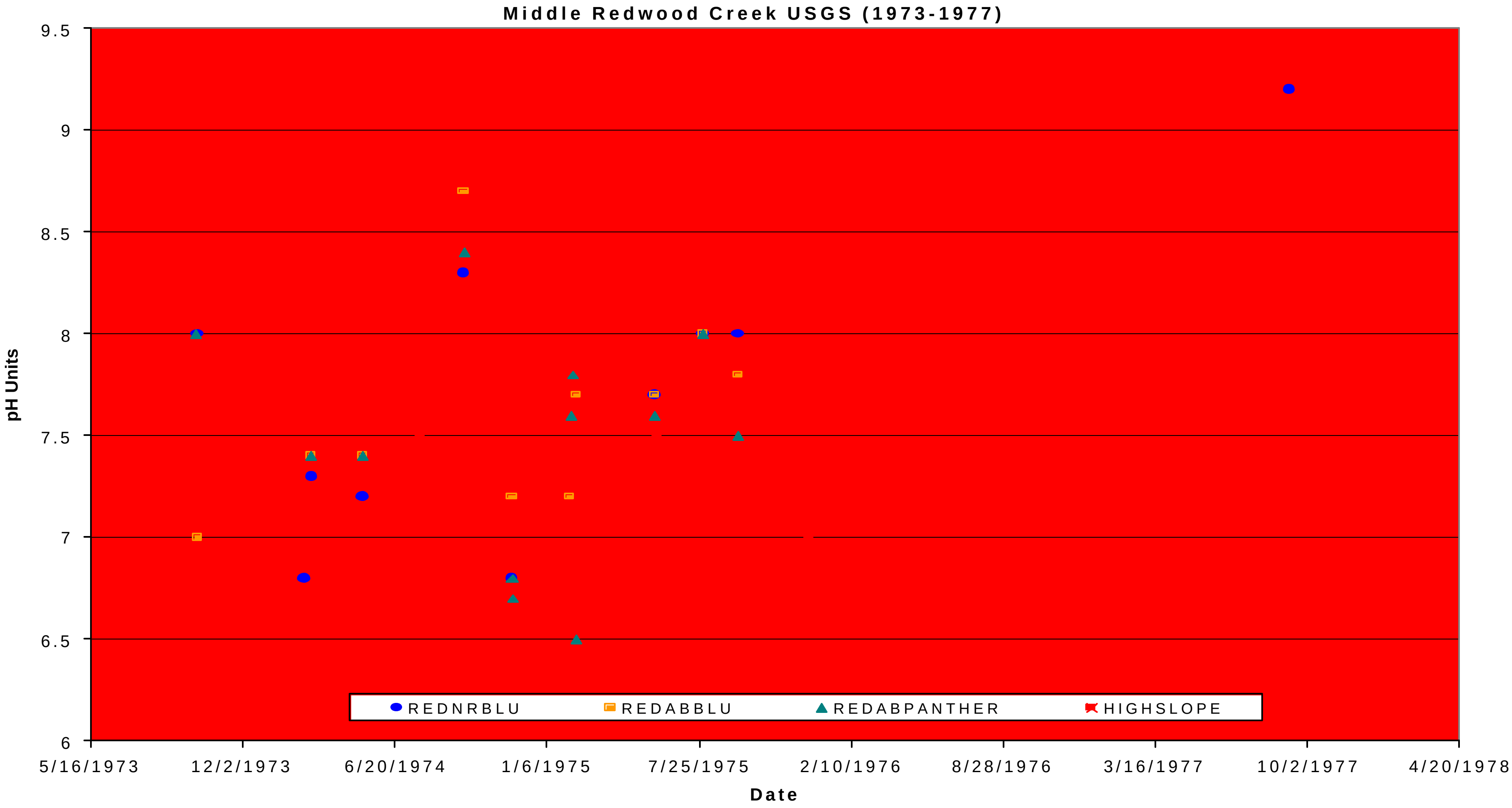


Figure 28: USGS data for pH for the period of record 1973-1977 for Middle Redwood Creek (incorporates O'kane/RedNrBlu station).
Data source: [2]USGS (2001)

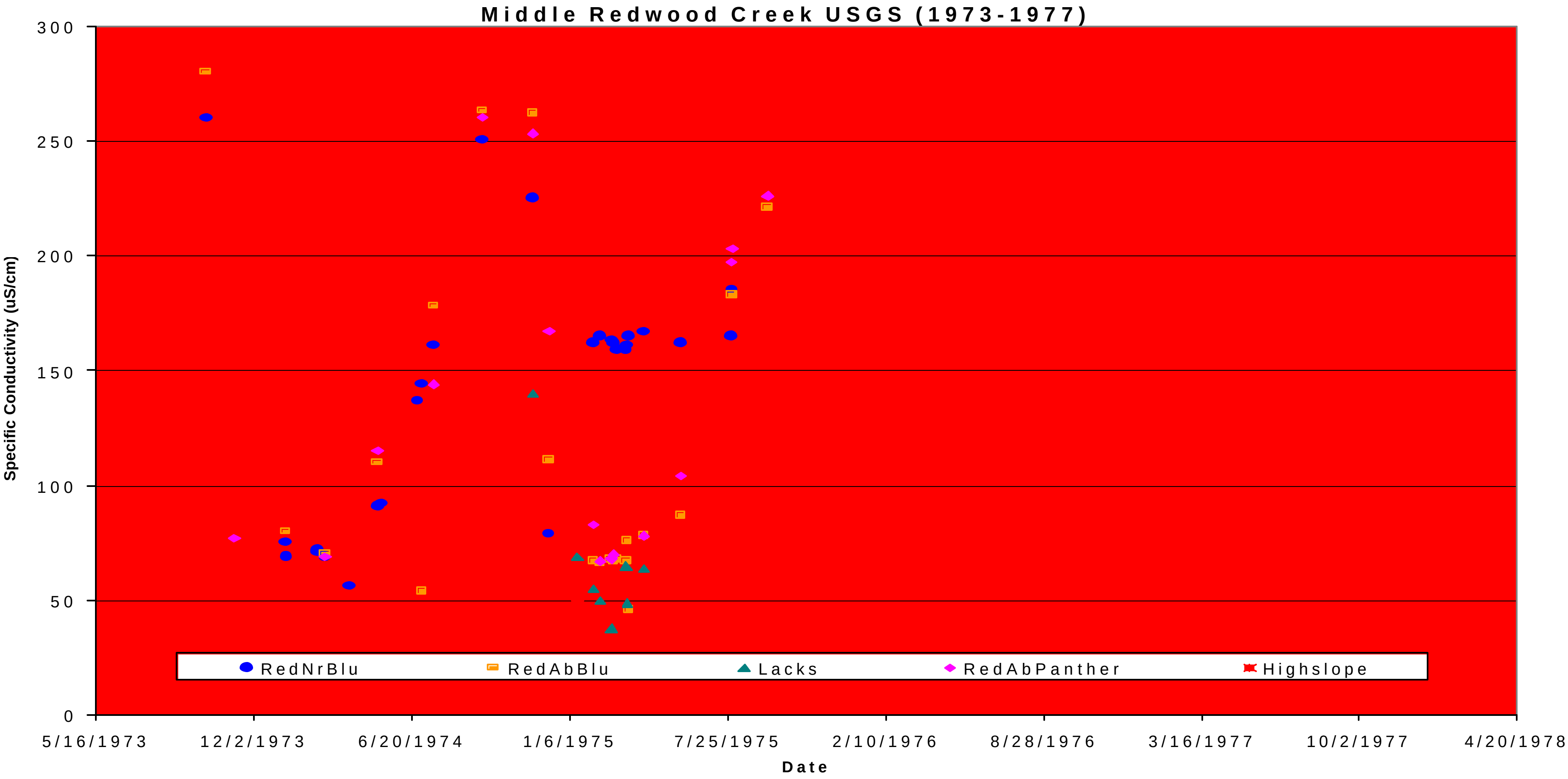


Figure 29: USGS data for conductance for the period of record 1973-1977 for Middl e Redwood Creek (incorporates O'kane/RedNrBlu station). Data source: [2]USGS (2001)

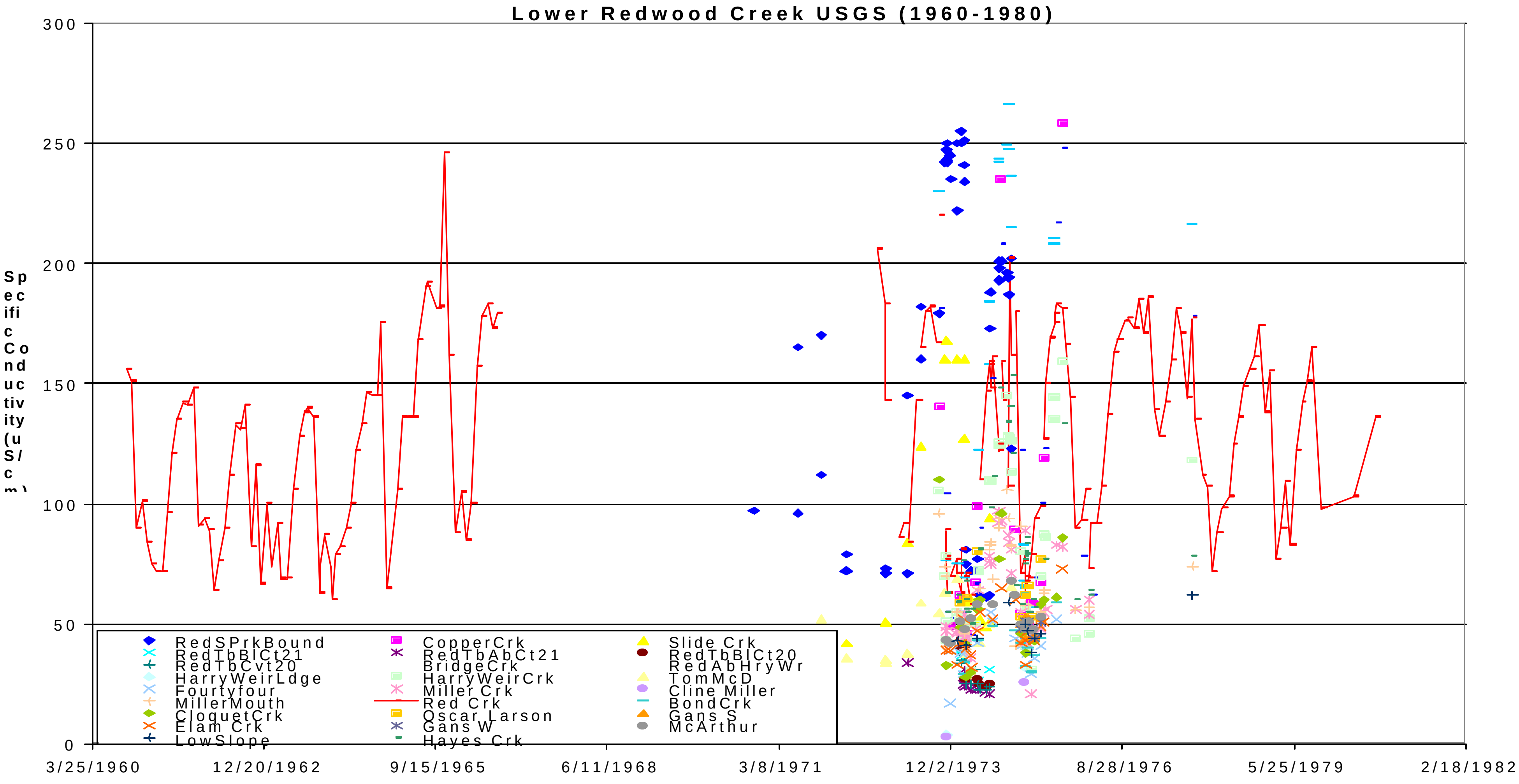


Figure 23: USGS data for conductance for the period of record 1960-1980 for Lower Redwood Creek
Data source: [2]USGS (2001)

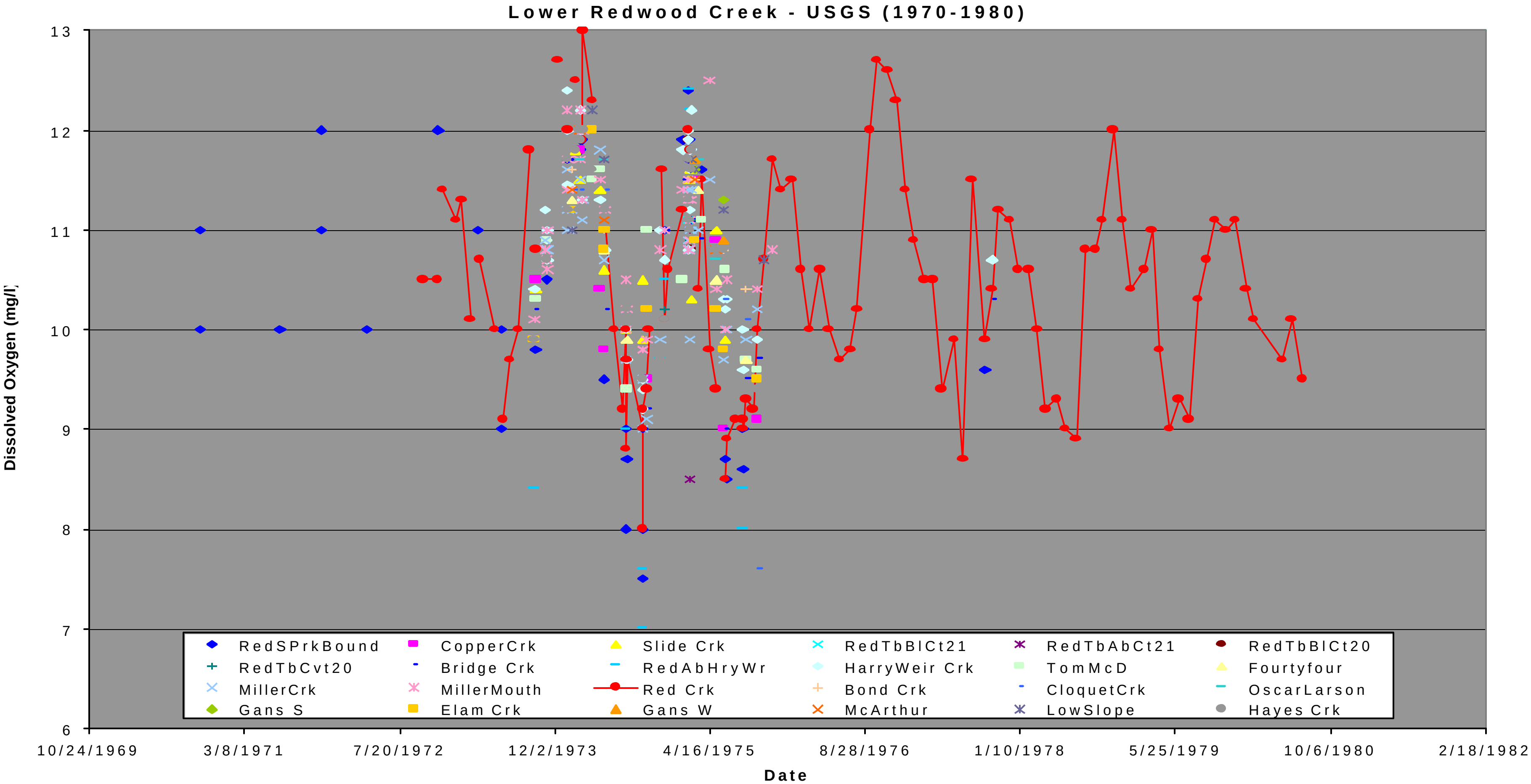


Figure 24: USGS data for dissolved oxygen for the period of record 1960-1980 for Lower Redwood Creek
Data source: [2]USGS (2001)

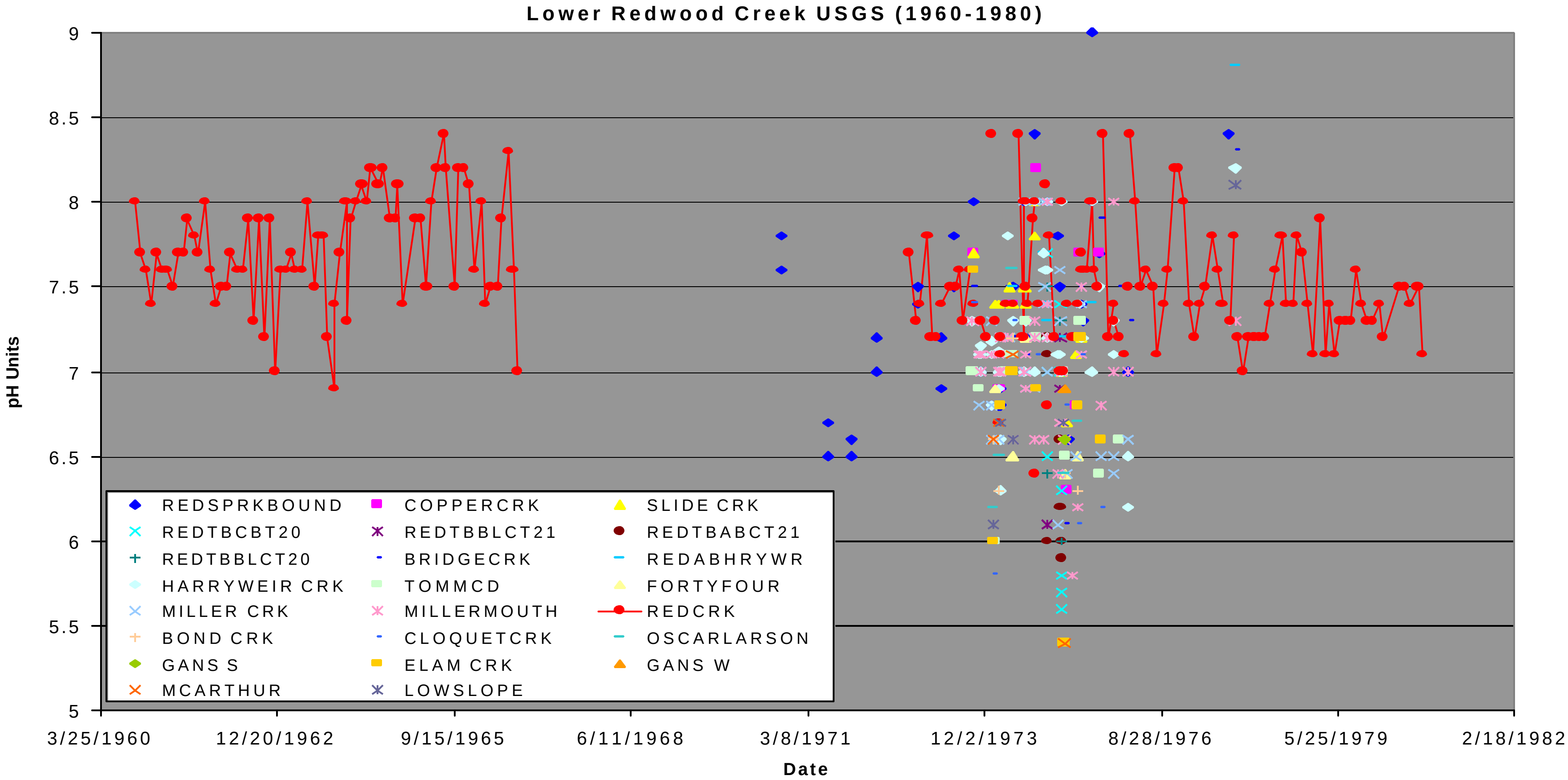


Figure 25: USGS data for pH for the period of record 1960-1980 for Lower Redwood Creek
Data source: [2]USGS (2001)

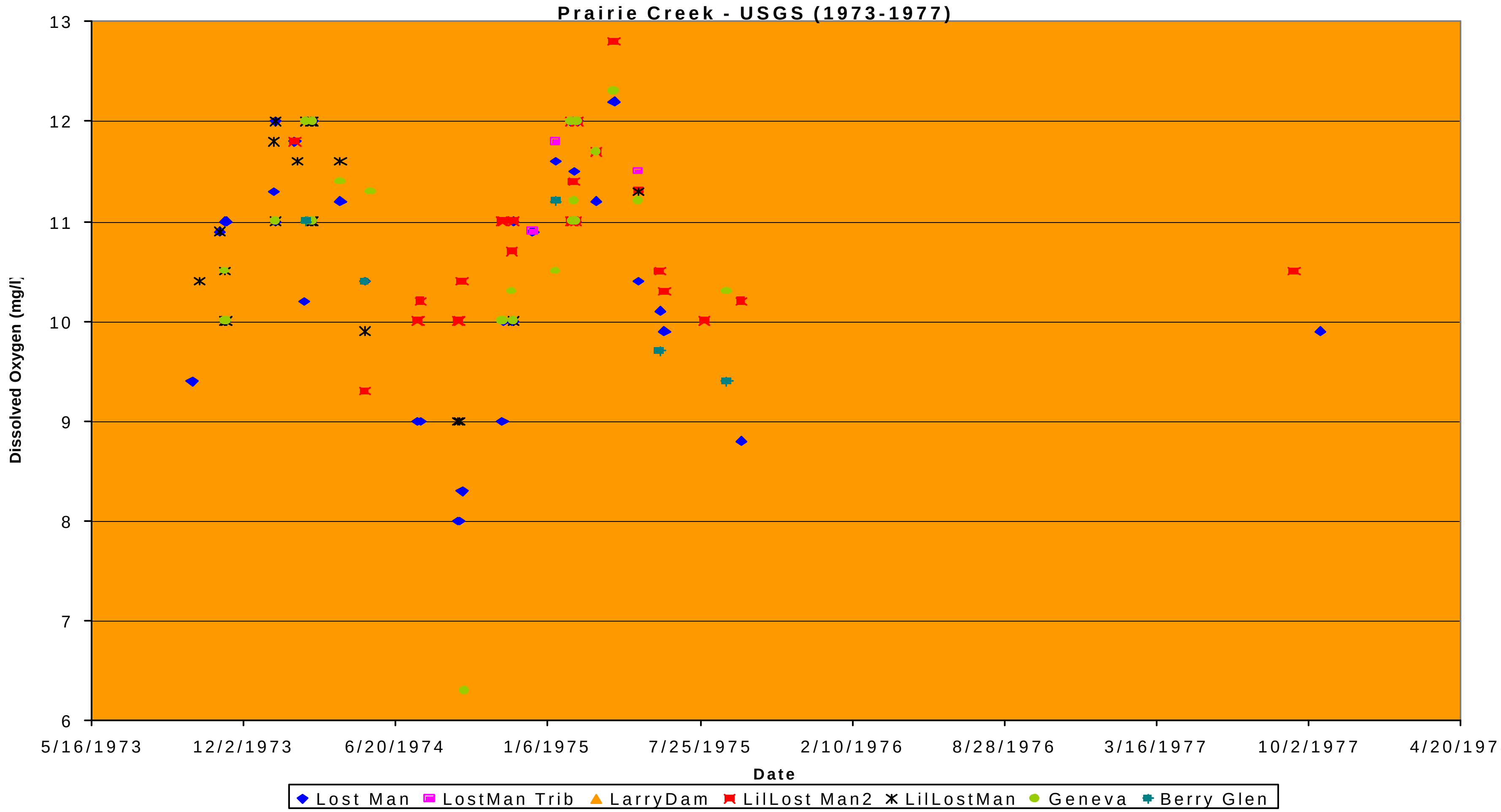


Figure 20: USGS data for dissolved oxygen for the period of record 1960-1980 for Prairie Creek
Data source: [2]USGS (2001)

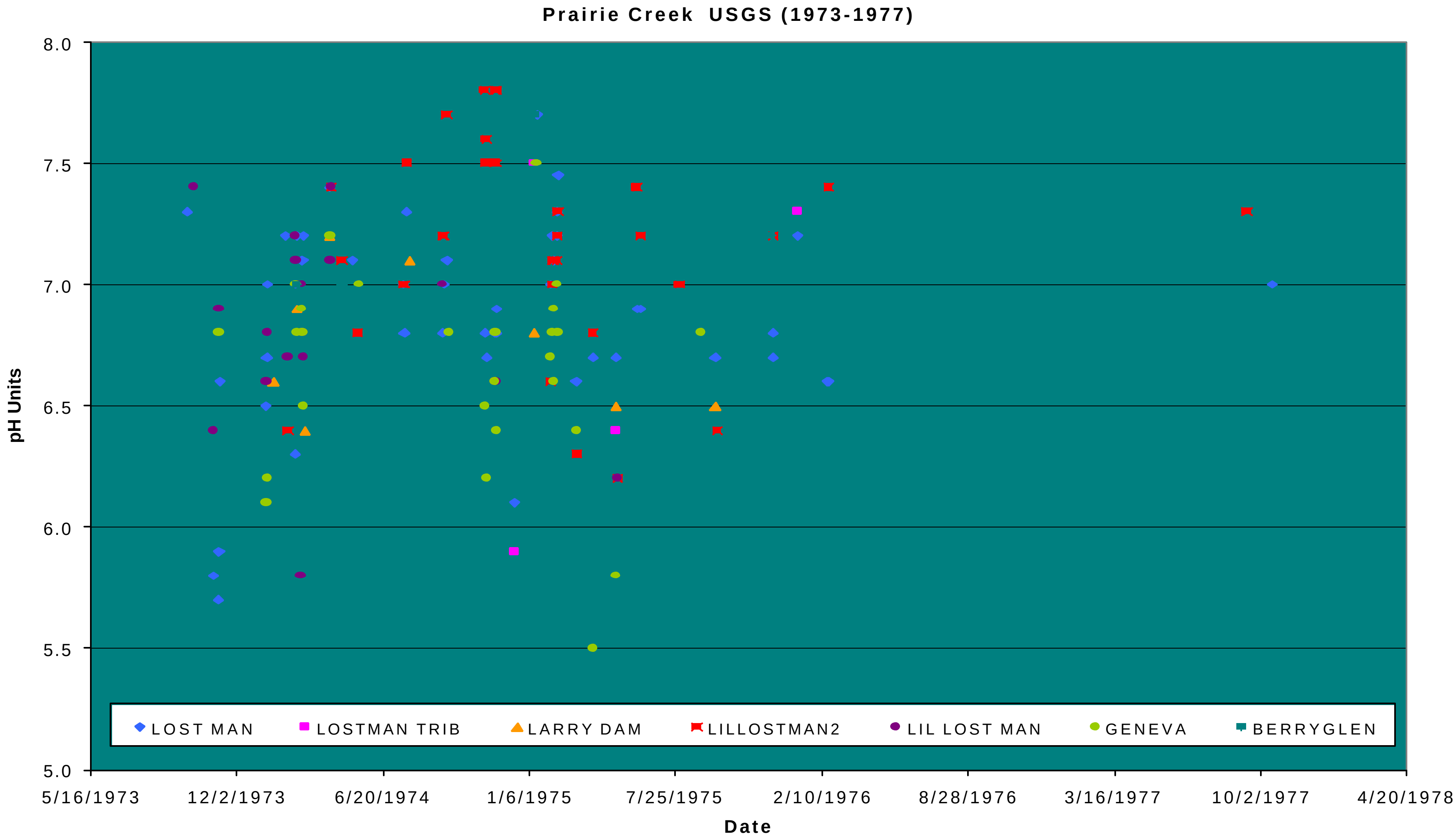


Figure 21: USGS data for pH for the period of record 1960-1980 for Prairie Creek
Data source: [2]USGS (2001)

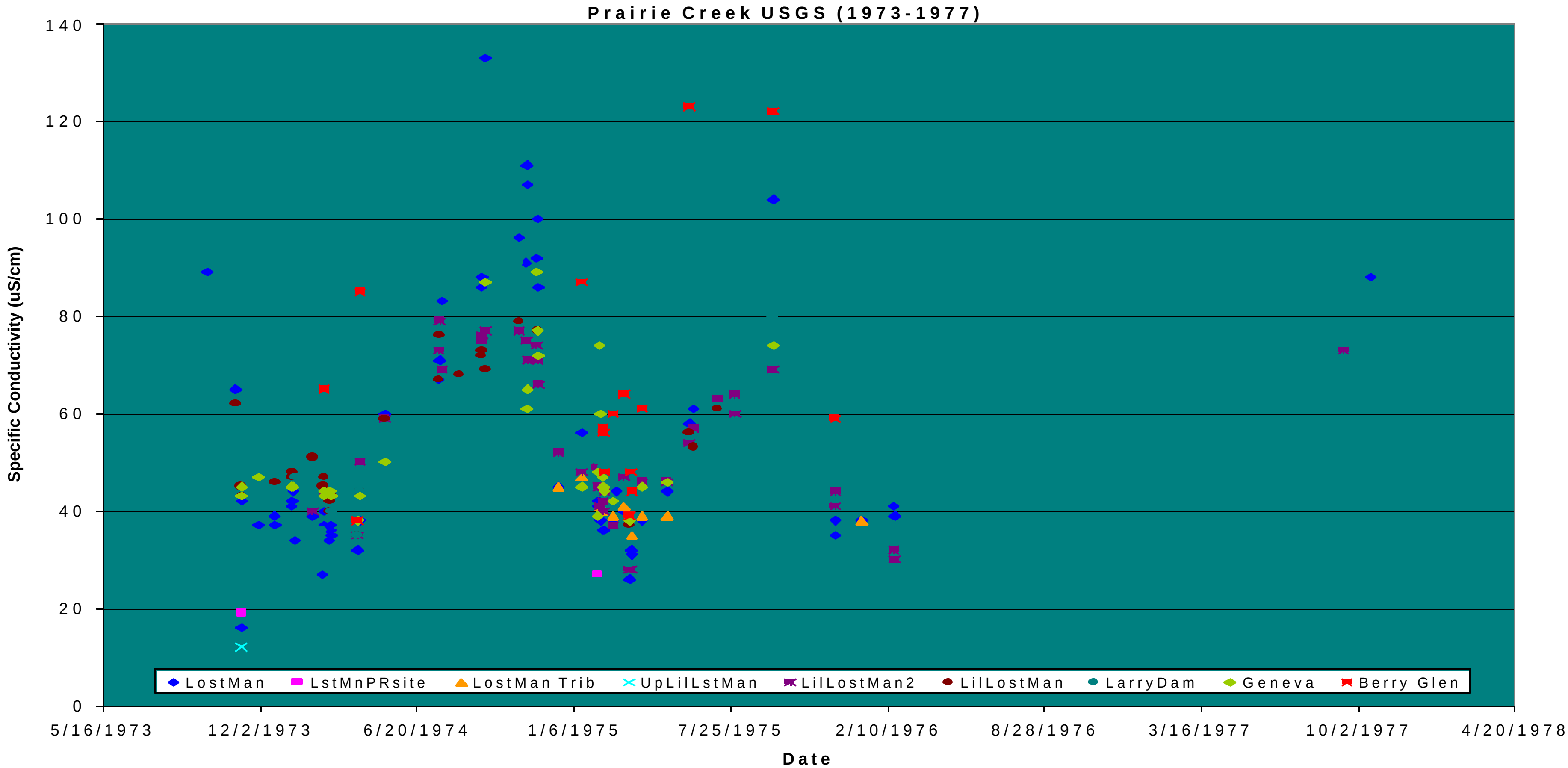


Figure 22: USGS data for conductance for the period of record 1960-1980 for Prairie Creek
Data source: [2]USGS (2001)

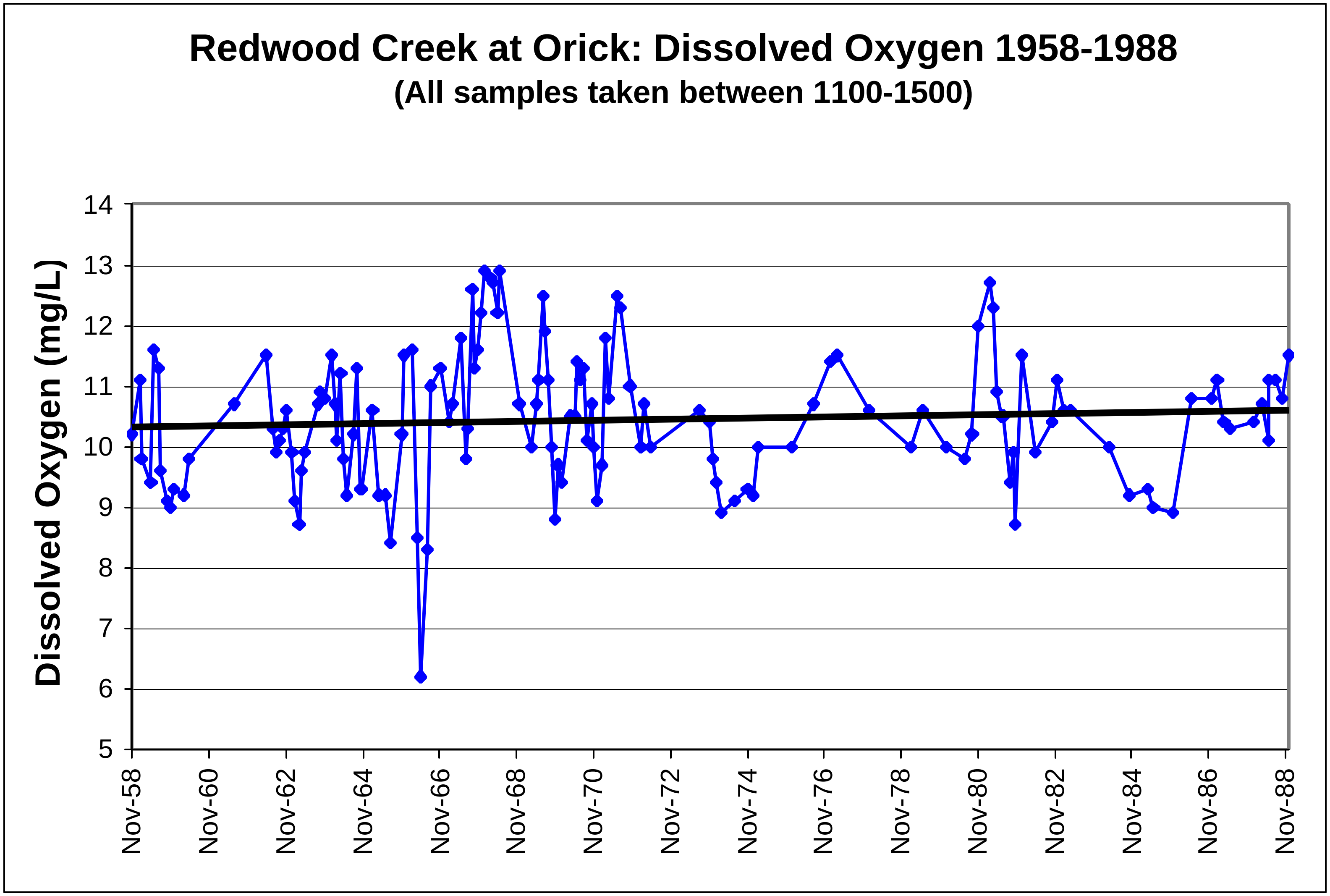


Figure 15: StoRet data for dissolved oxygen for the period of record 1958-1985 for Orick
Data source: [4]EPA (2001)

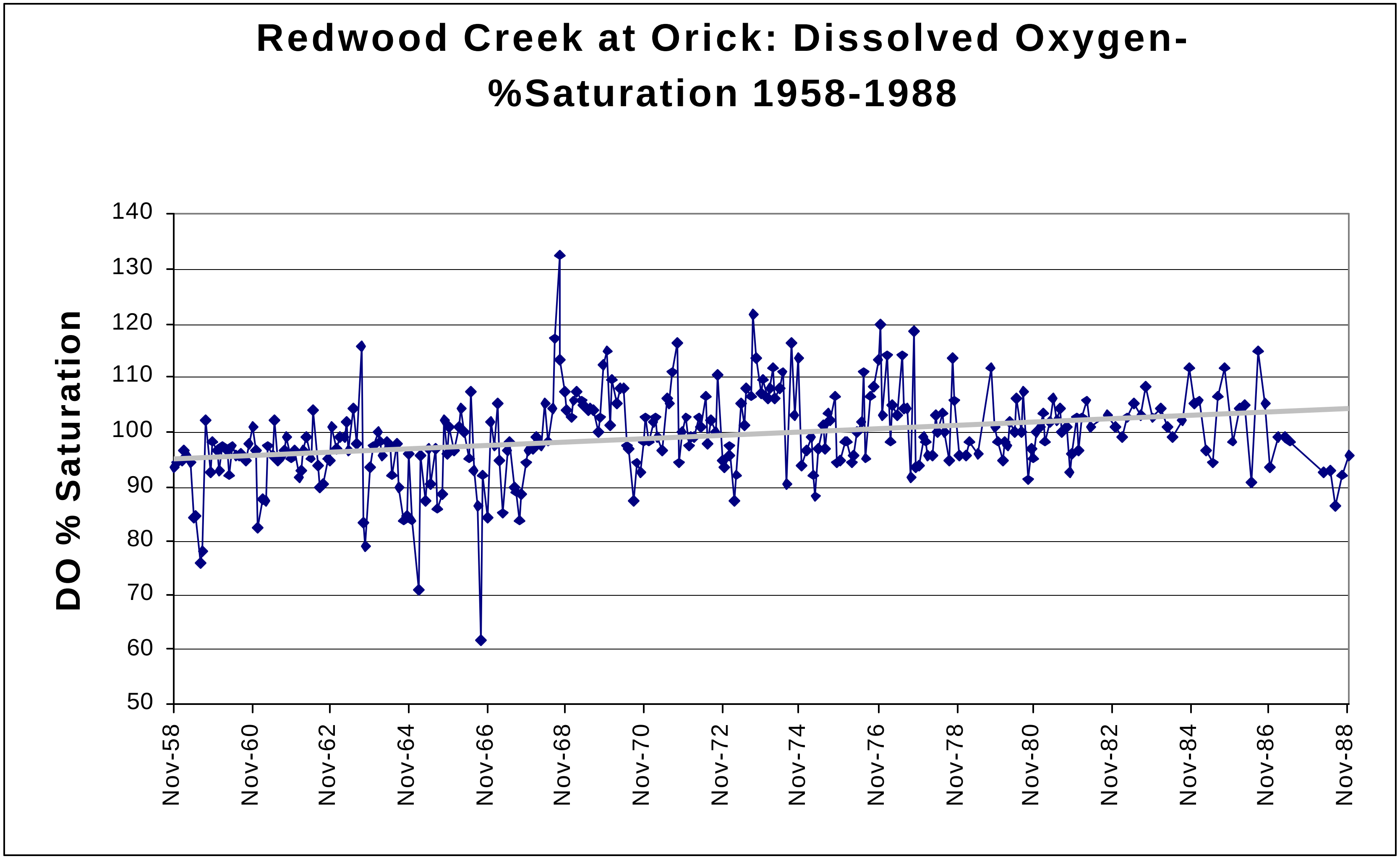


Figure 16: StoRet data for percent saturation of dissolved oxygen for the period of record 1958-1985 for Orick Data source: [4]EPA (2001)

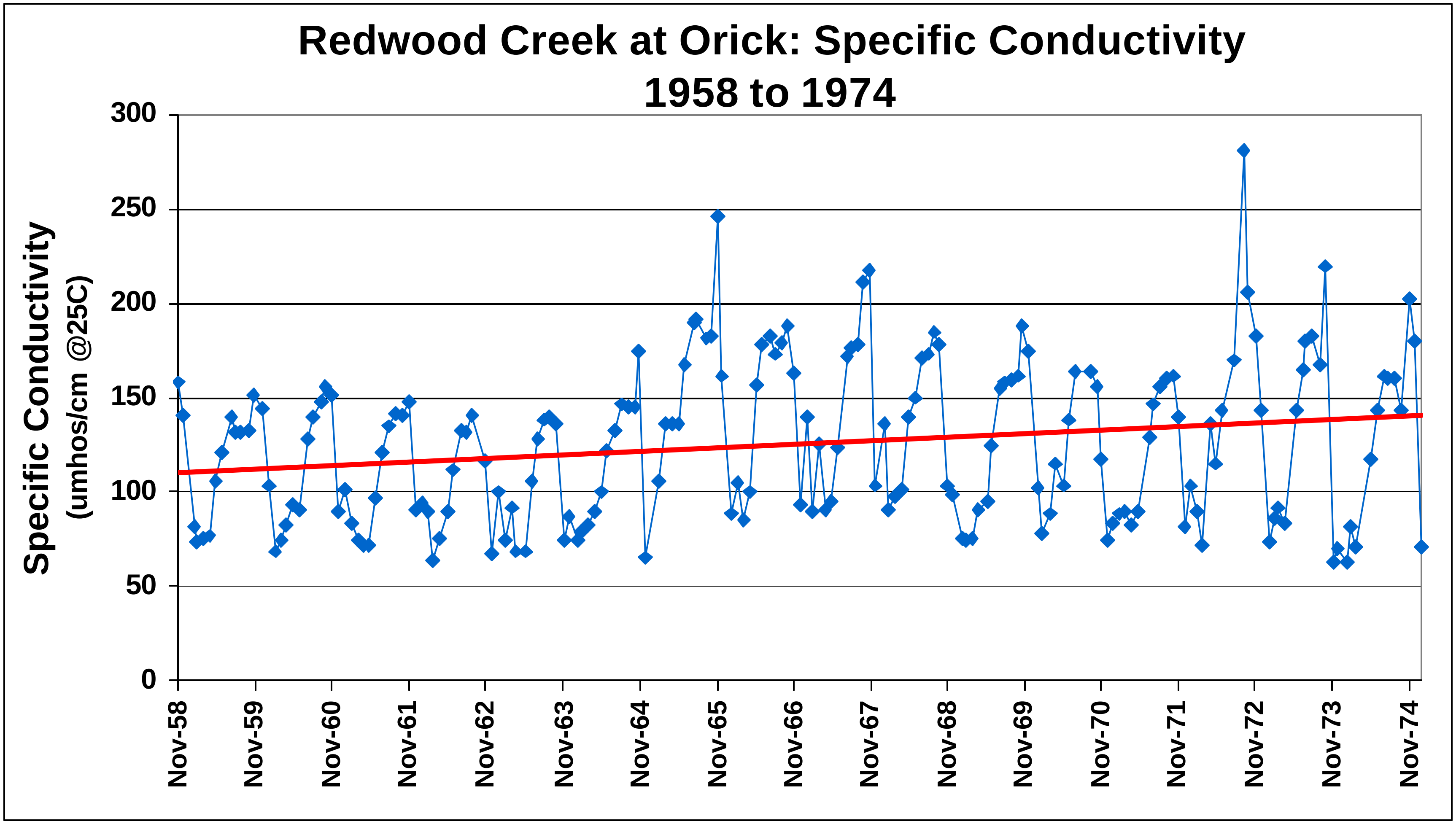


Figure 17: StoRet data for conductance for the period of record 1958-1985 for Orick
Data source: [4]EPA (2001

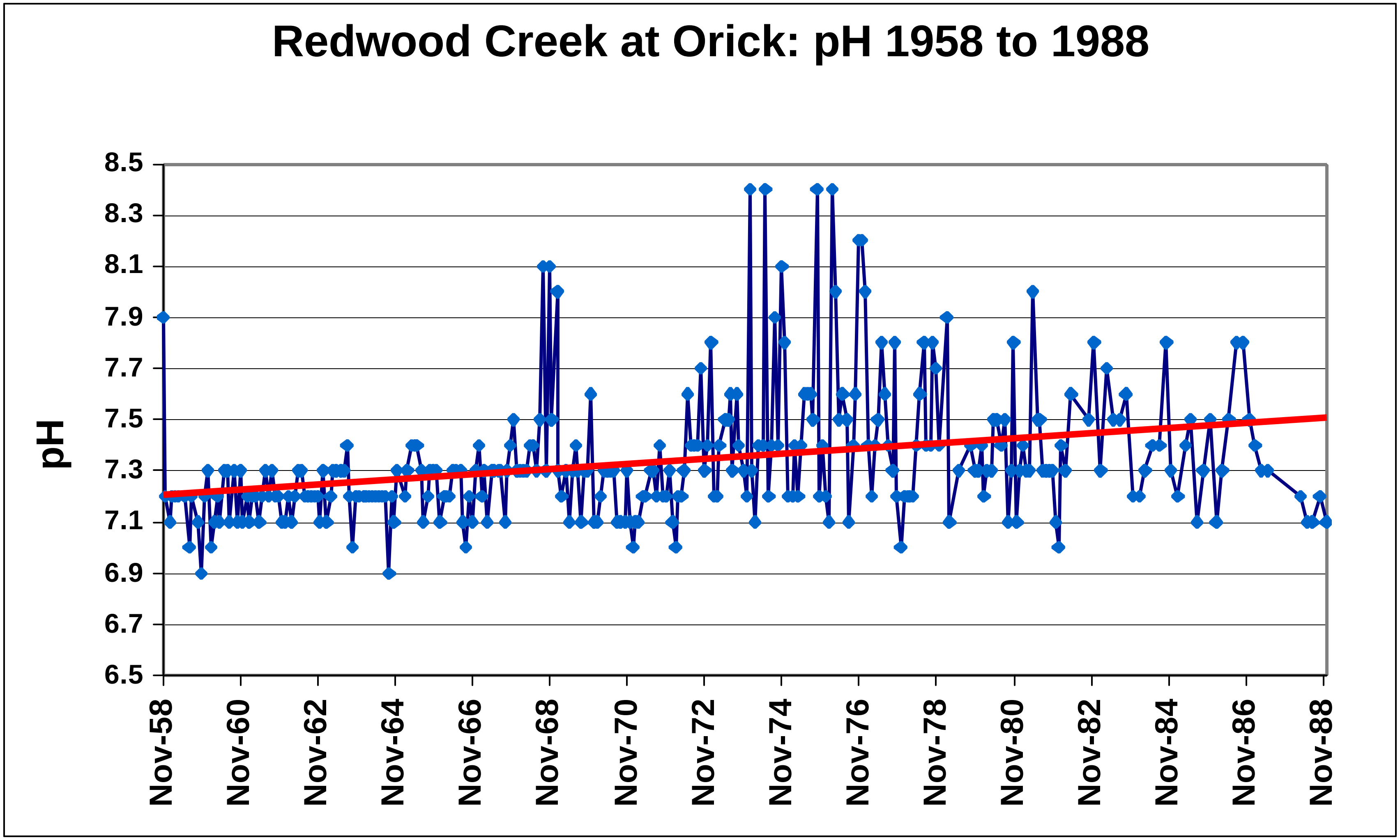


Figure 18: StoRet data for pH for the period of record 1958-1985 for Orick
Data source: [4]EPA (2001)

Table 9: USGS nutrients data from 1973-1976 from the Redwood Creek station at Orick.
Data source: [2]USGS, 2001

USGS[2]	Date	Sample Time	607 Organic Dissolved N (mg/LN)	608 Dissolved Ammonia (mg/LN)	613 Dissolved Nitrite (mg/LN)	618 Dissolved Nitrate (mg/LN)	620 Total Nitrate (mg/LN)	623 Kjeldahl Dissolved N (mg/LN)	625 Total Kjeldahl N (mg/LN)	631 Dissolved Nitrite + Nitrate (mg/LN)	660 Ortho Phosphate (mg/LPO4)	665 Total P (mg/LP)	666 Dissolved Phosphorus (mg/L P)	671 Dissolved OrthoPhosphate (mg/L P)
Orick	11/13/73	15:45					0.09							
Orick	1/13/74	12:50			< 0.01	0.03		0.27		0.03	0		0.01	<0.01
Orick	2/21/74	13:00			< 0.01	1		0.2		1	0.03		0.01	0.01
Orick	4/1/74	14:35					0.07				0.06	3.1		0.02
Orick	7/19/74	12:00	0.03	0.04	< 0.01	0.03		0.07		0.03			0.07	
Orick	7/24/74	14:00	0	<0.01	< 0.01	0.03		<0.1		0.03			<0.01	
Orick	9/11/74	12:00	0.24	<0.01	< 0.01	0		0.24		<0.1			<0.01	
Orick	9/17/74	16:45	0.13	0.01	< 0.01	0.01		0.14		0.01			0.03	
Orick	4/14/75	13:50					0.04		0.2			0.11		
Orick	6/2/75	16:30	0.04	0.01	< 0.01	0		0.05		<0.1	0.03		0.02	0.01
Orick	6/8/75	17:30	3.3	<0.01	< 0.01	0		3.3		<0.1	0.03		0.01	0.01
Orick	4/5/76	14:15				0.03			0.1		0	0.1		<0.01

Site / Usability	Notes	Problems cited by RNSP
1999 **Redwood Creek upstream of Tom McDonald Creek (RWVAL99W)** Data appears to be completely unusable.	Problems began around 6/29. By mid/end of July, there were 20 deg F temp swings in a day and then things generally stayed bad for the remainder of the logged time period. Large temp swings almost allways happened between 2 and 6 pm. By the end of August, water temps seem to closely track air temps.	Half submerged when pulled on 12/15/99.
1999 **Redwood Creek upstream of Minon Creek (RWMIN99W)** Data may be usable. Suggest to plot out data, point out areas of concern, but not use the data in assessment at this point. Follow up with field check.	Numerous temp swings (>4) between 8/20 and 9/18 always between 11 am and 12 pm. 1 isolated swing at 7/13. The amplitude of the temp swings in the water never comes close to matching that of the air, so the probe was probably not out of the water.	Graph should start on 6/2/99. Weird data from 6/1 to 6/2.
1999 **Minor Creek (MIN99W)** Data appears to be completely unusable with the possible exception of a large part of June (until ~6/27).	>4 degree temp swings at about 1-2 pm, many days following 7/15 when problems seemed to begin. No air temps, but it appears as that the amplitude of the water temp swings jumps shortly before and following 7/15. These swings reach ~20 deg F each day.	Probe found half submerged.
2001 **Redwood Creek upstream of Lacks Creek (RWVAL01)** Data may be usable. Suggest to plot out data, point out areas of concern, but not use the data in assessment at this point. Follow up with field check.	6 occasions where temp swings exceeded 4 deg F, often in the early afternoon. Plot against air temp suggests that probe remained submerged. largest 24 hour temp swing is 20 deg F, but generally temp swings were 15 deg F or less.	Nothing noted.
2001 **Redwood Creek Estuary (RWEST01W)** Data may be usable. Suggest to plot out data, point out areas of concern, but not use the data in assessment at this point. Follow up with field check or possibly location evaluation via GIS. Location may reinforce or detract from cold water "wedge" theory.	Some very large temp swings at various dates (>10 deg F in 1 hour), which almost always occur between 9 pm and midnight. Graph generally looks influenced by ocean, but instances of large temp fluctuations maybe due to salt water wedge, levee breach, etc.	Nothing noted.

Table 8: Comments on problems with raw temperature data received from RNSP for 1999 and 2001 locations.

Figure 3: Raw temperature plot for 1999 of mainstem site upstream from Lacks Creek. Data source: RNSP (2001)

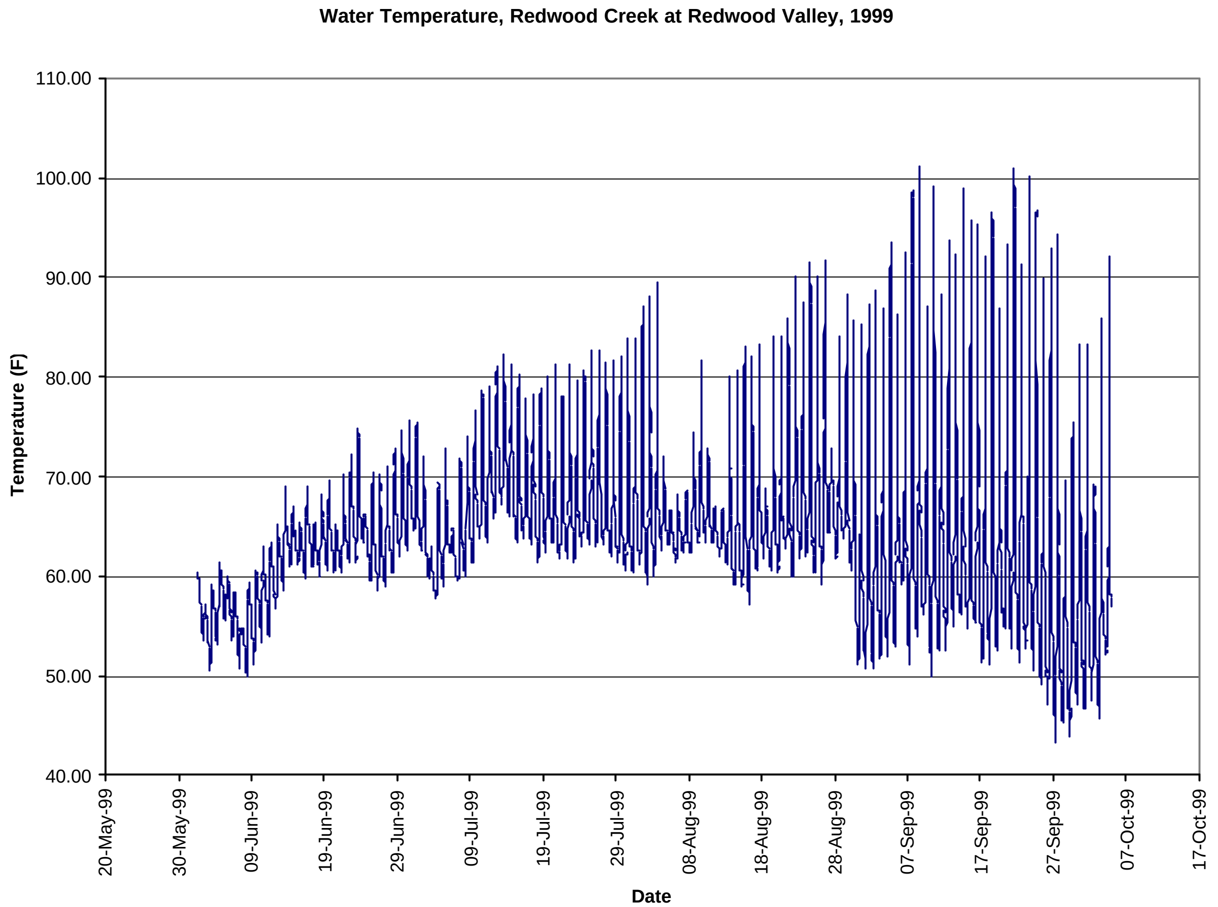


Figure 4: Close-up of problem temps on 7/3-8/99 for site upstream from Lacks Creek. Data source: RNSP (2001)

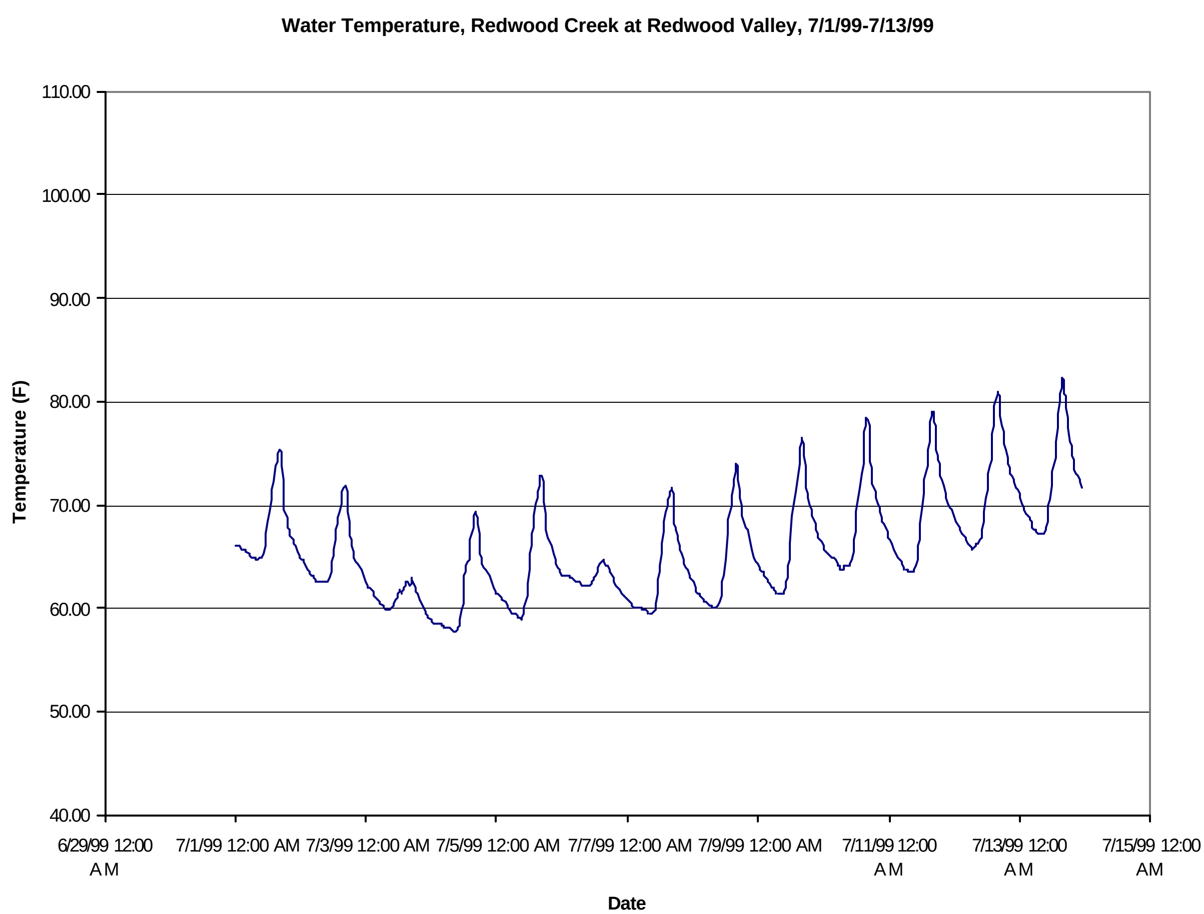


Figure 5: Raw temperature plot for 1999 for site upstream from Minon Creek.
Data source: RNSP (2001)

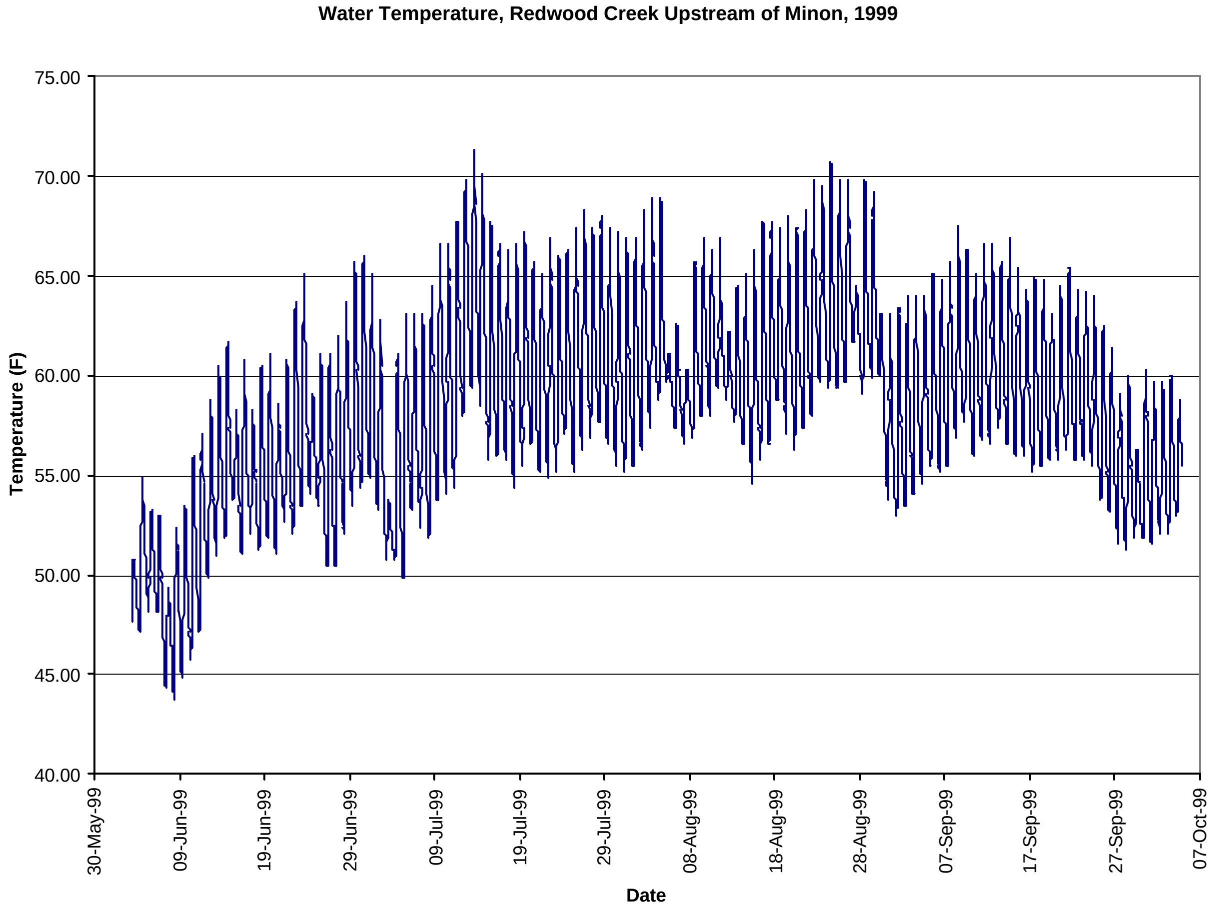


Figure 6: Close-up of problem temps on 8/28/99 for site upstream from Minon Creek.
Data source: RNSP (2001)

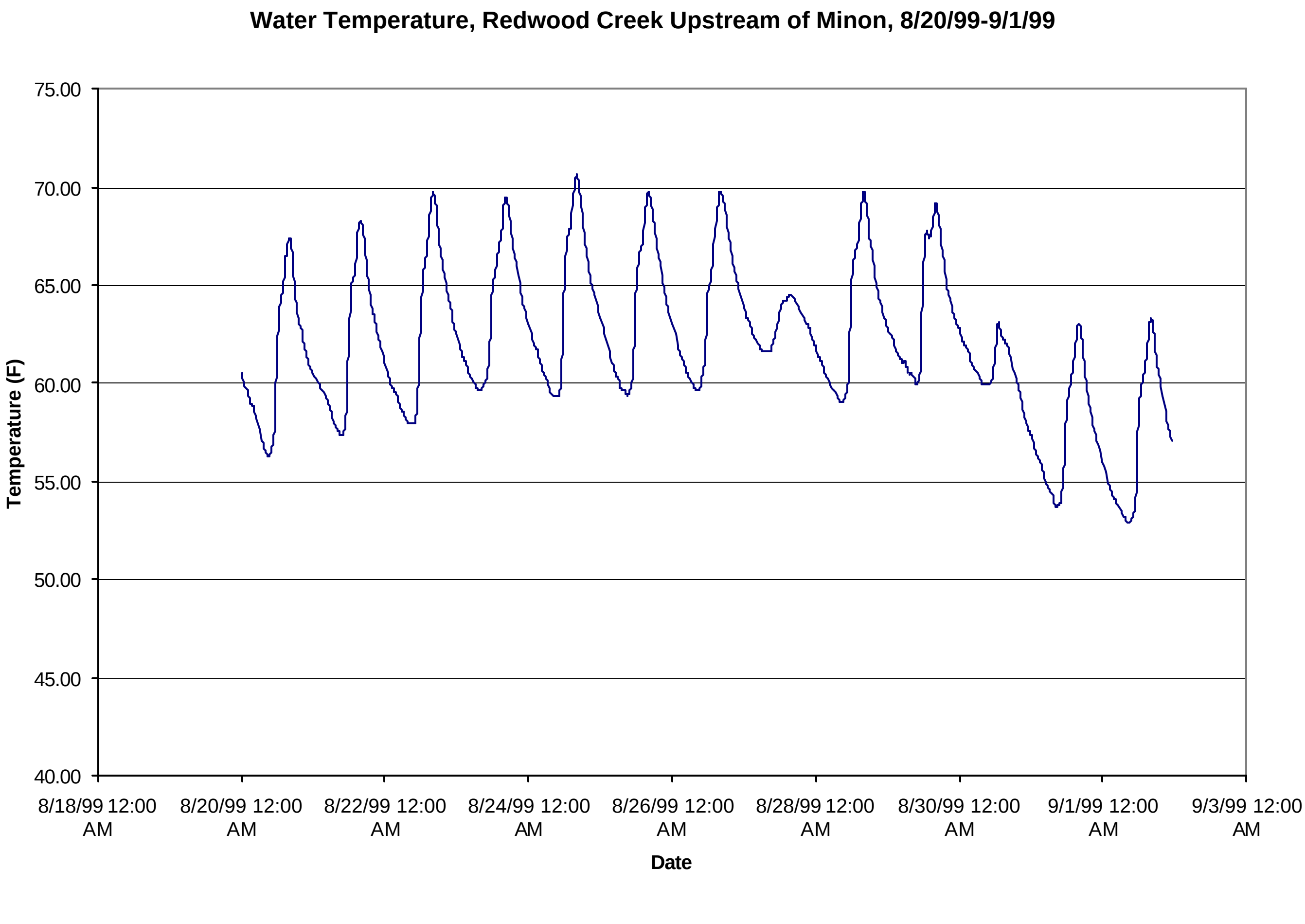


Figure 7: Raw temperature plot for 1999 for site at Minor Creek.
Data source: RNSP (2001)

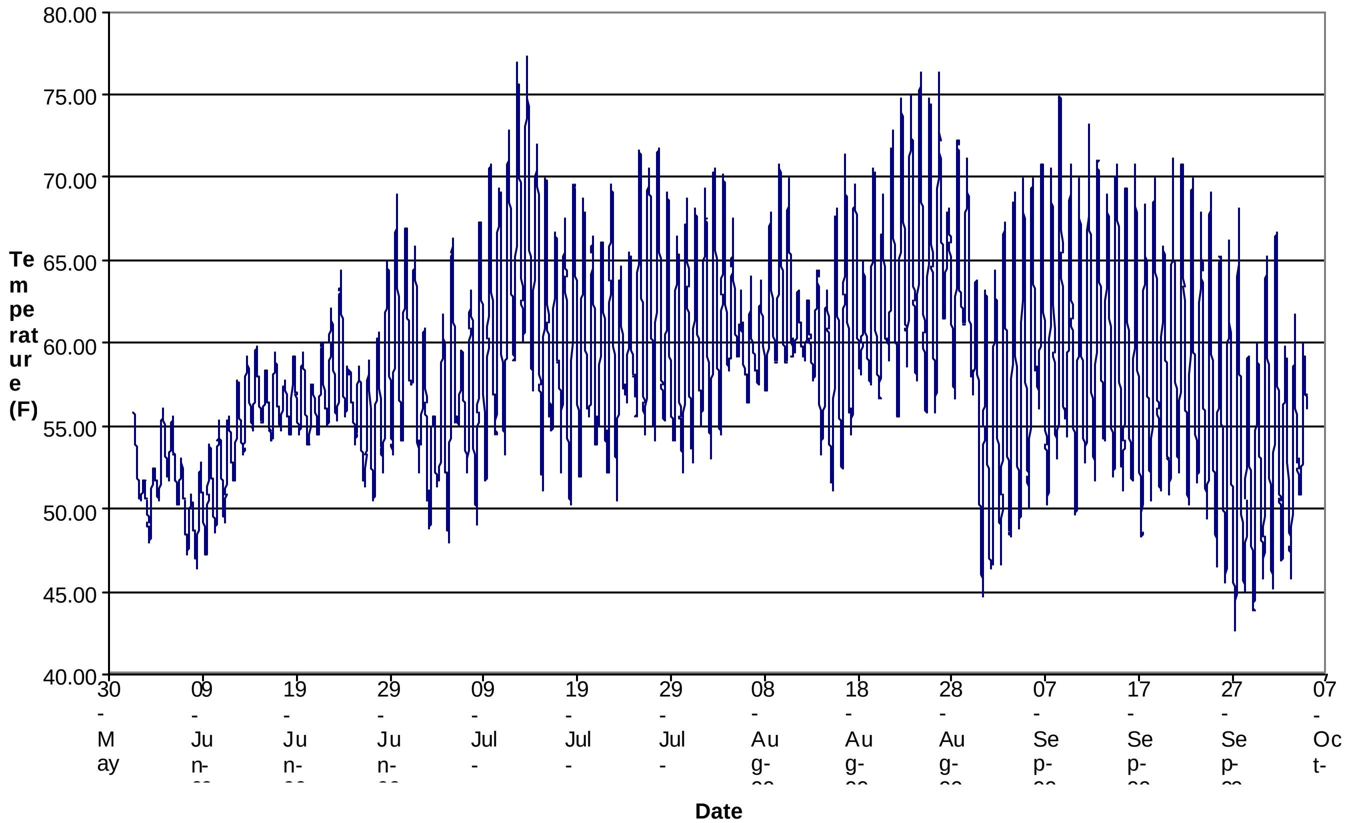


Figure 8: Close-up of problem temps on 8/29-31/99 for site at Minor Creek.
Data source: RNSP (2001)

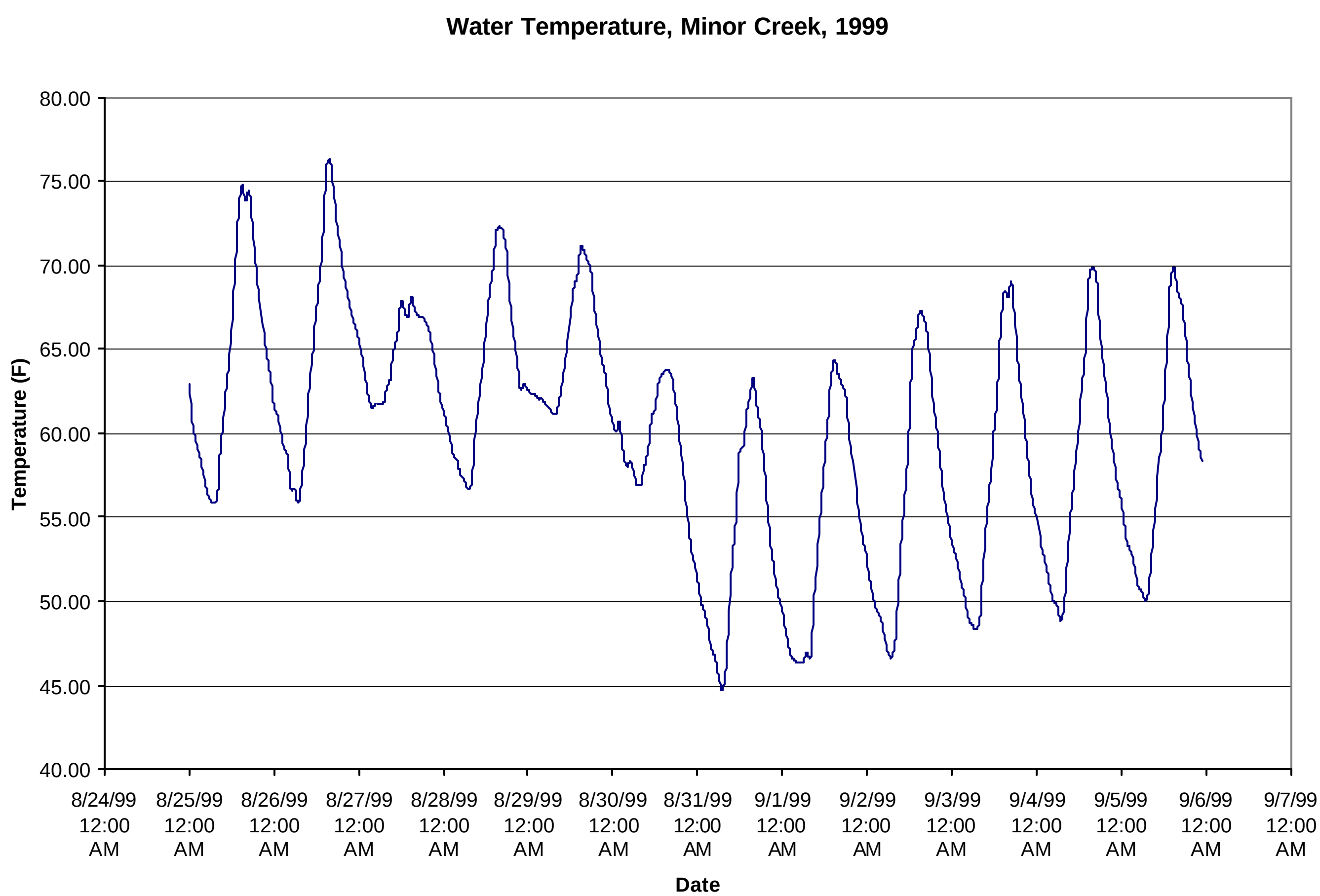


Figure 9: Raw temperature plot for 2001 of Redwood Creek Estuary. Data source: RNSP (2001)

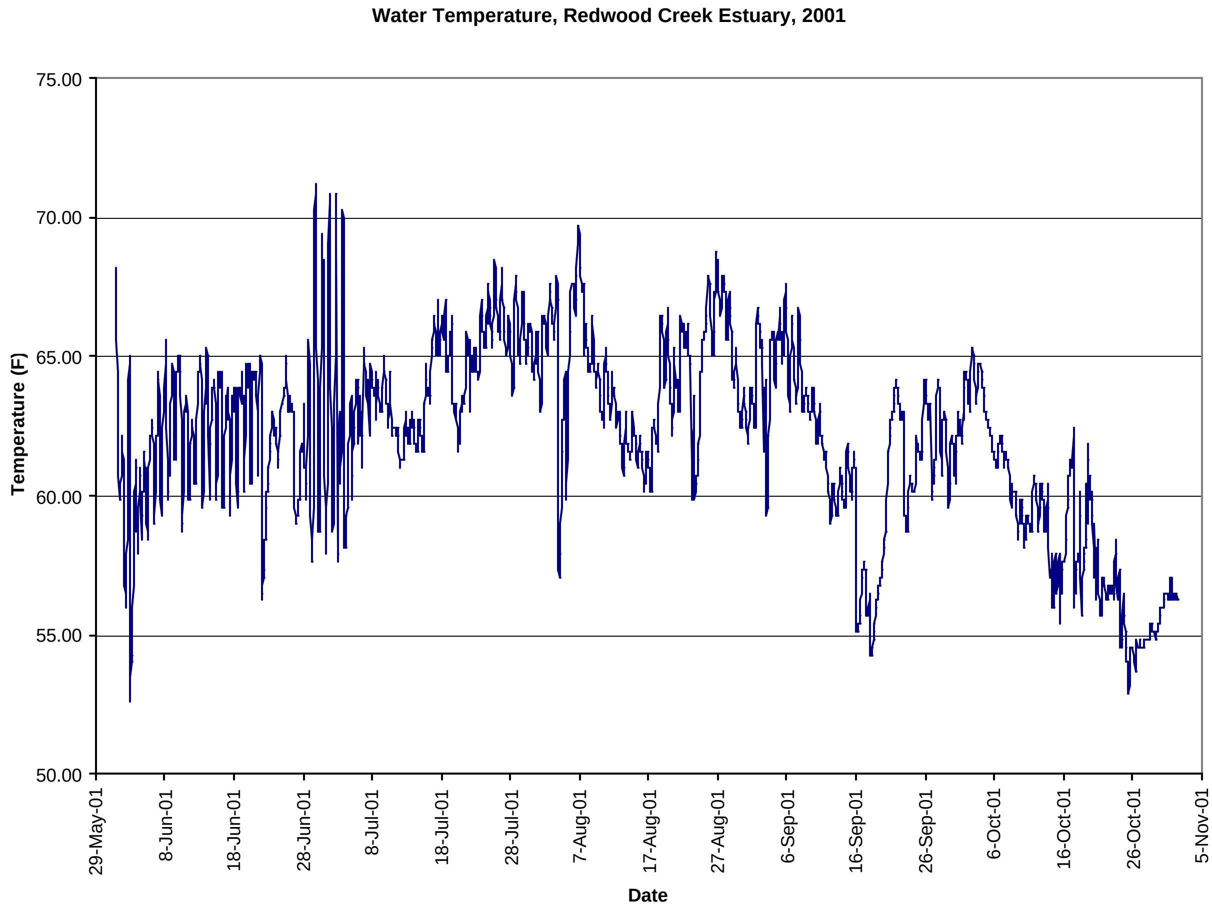


Figure 10: Close-up of problem temps on 8/4/01 for site at Redwood Creek Estuary. Data source: RNSP (2001)

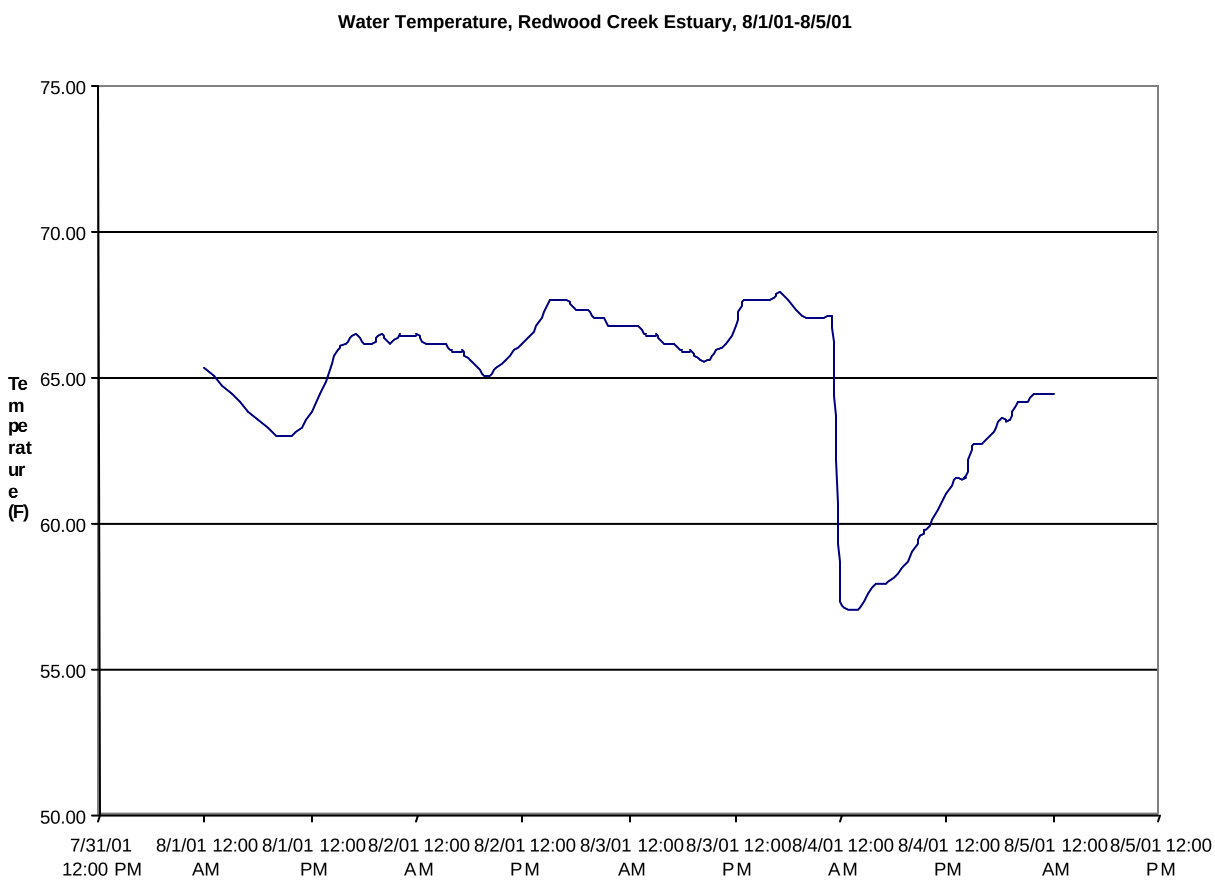


Figure 11: Raw temperature plot for 2001 of mainstem site upstream from Lacks Creek. Data source: RNSP (2001)

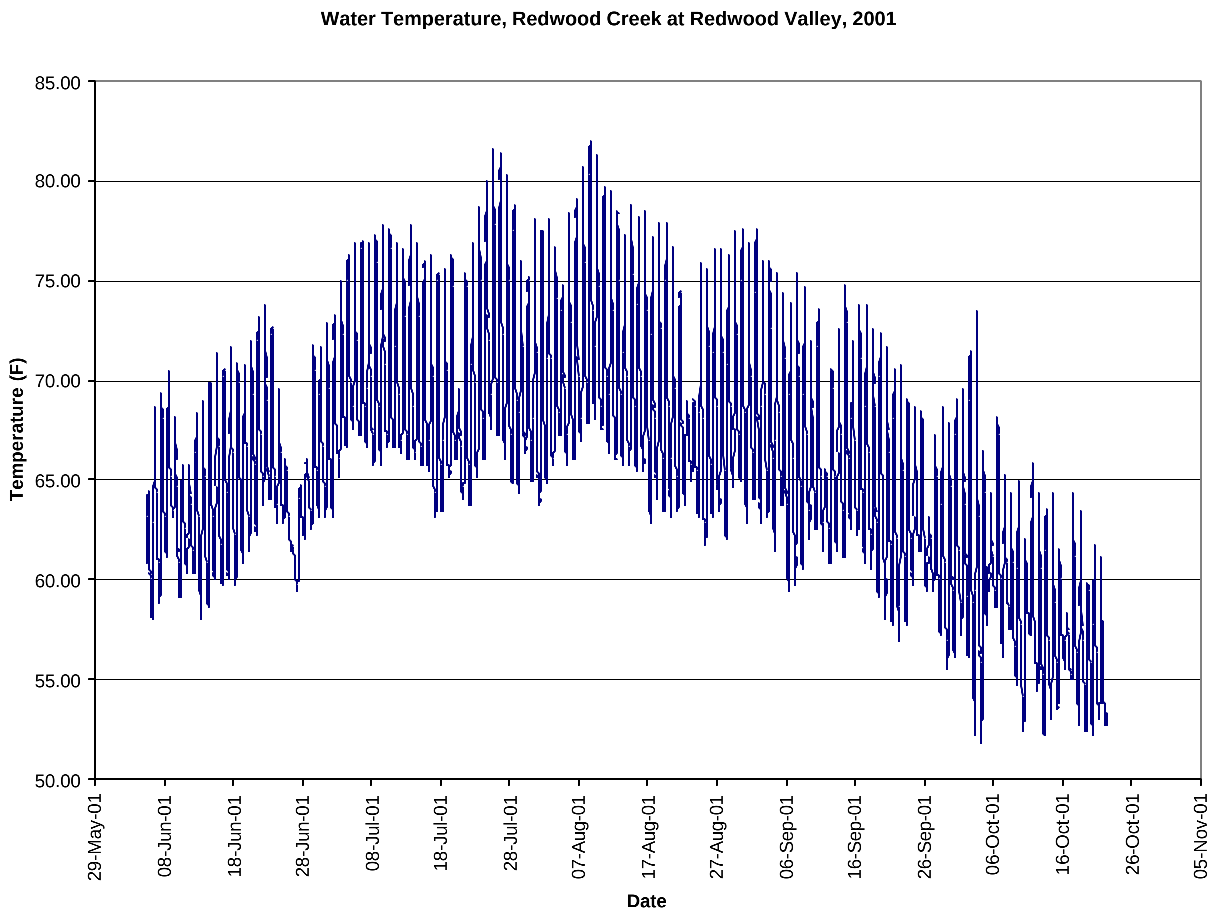


Figure 12: Close-up of problem temps on 8/22-25/01 for site upstream from Lacks Creek. Data source: RNSP (2001)

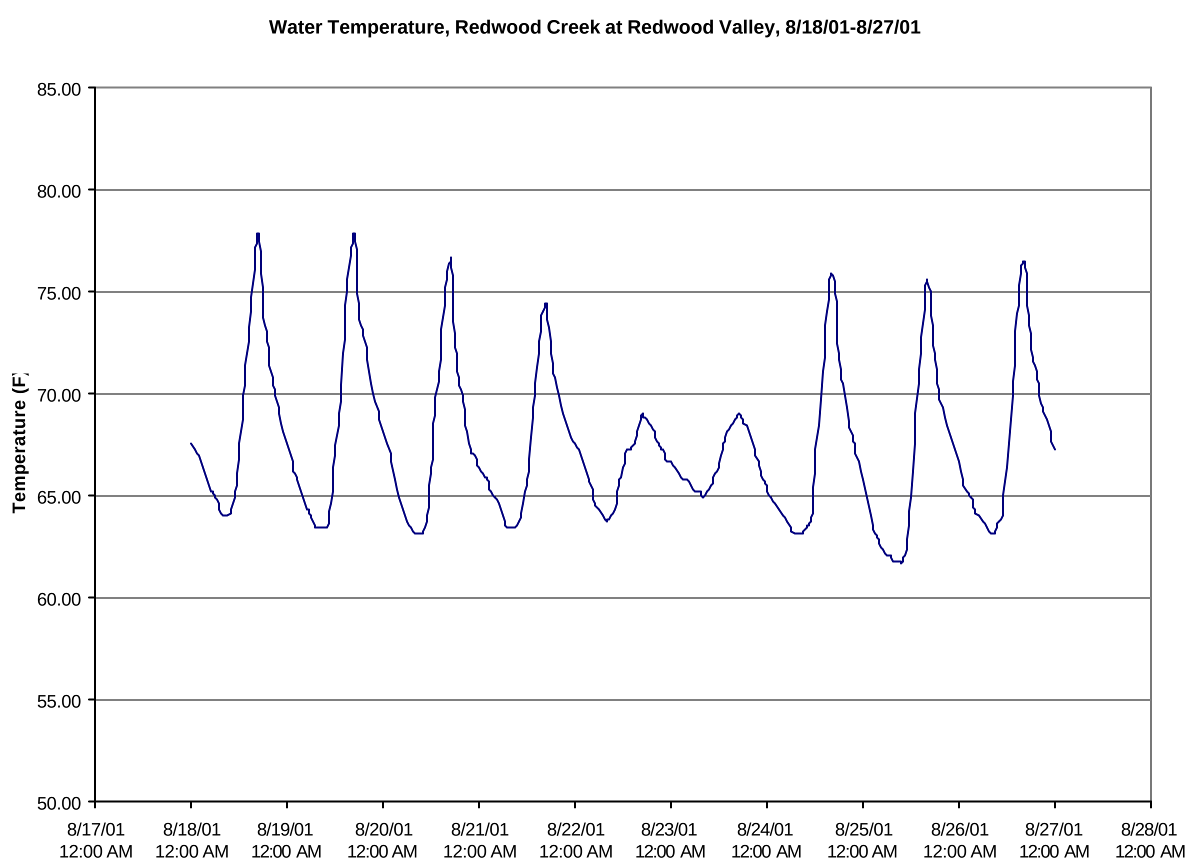
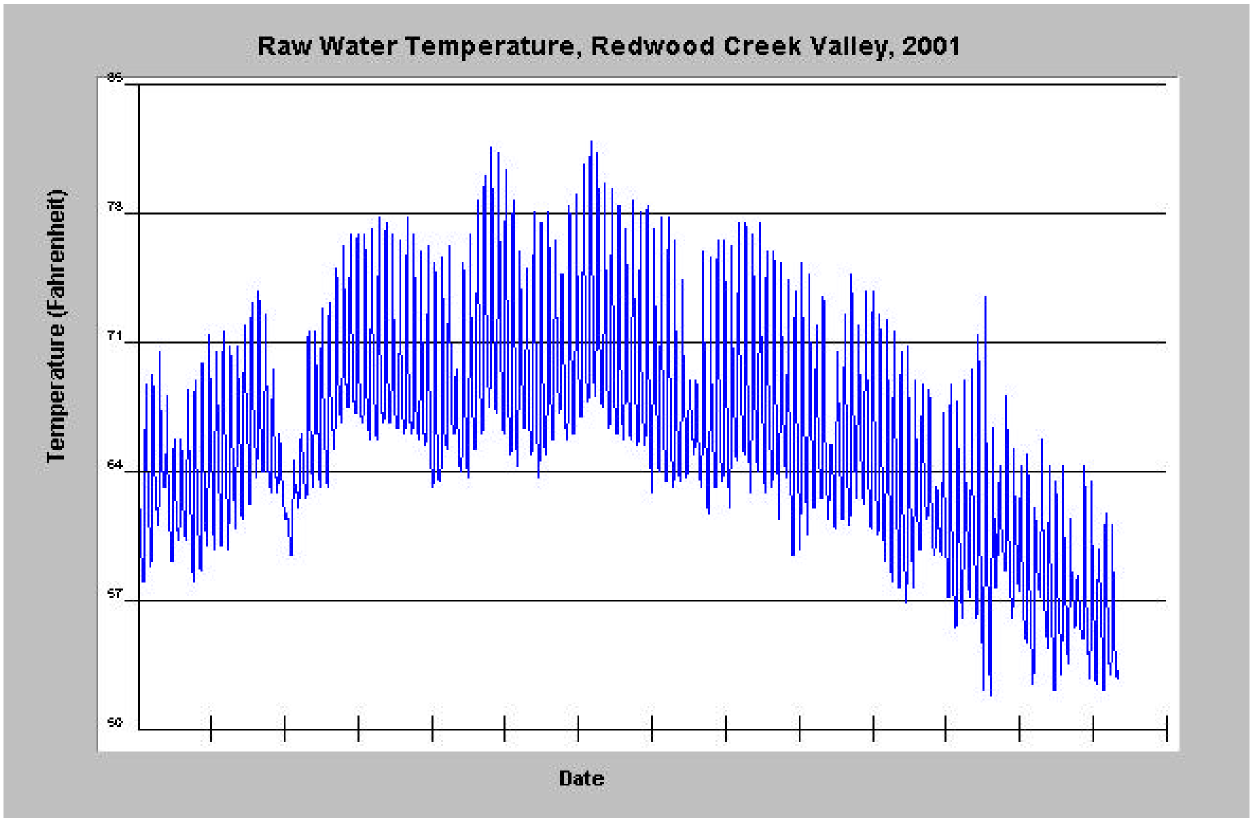


Figure 13: Raw temperature plotted in KRIS for 2001 of mainstem site upstream from Lacks Creek.



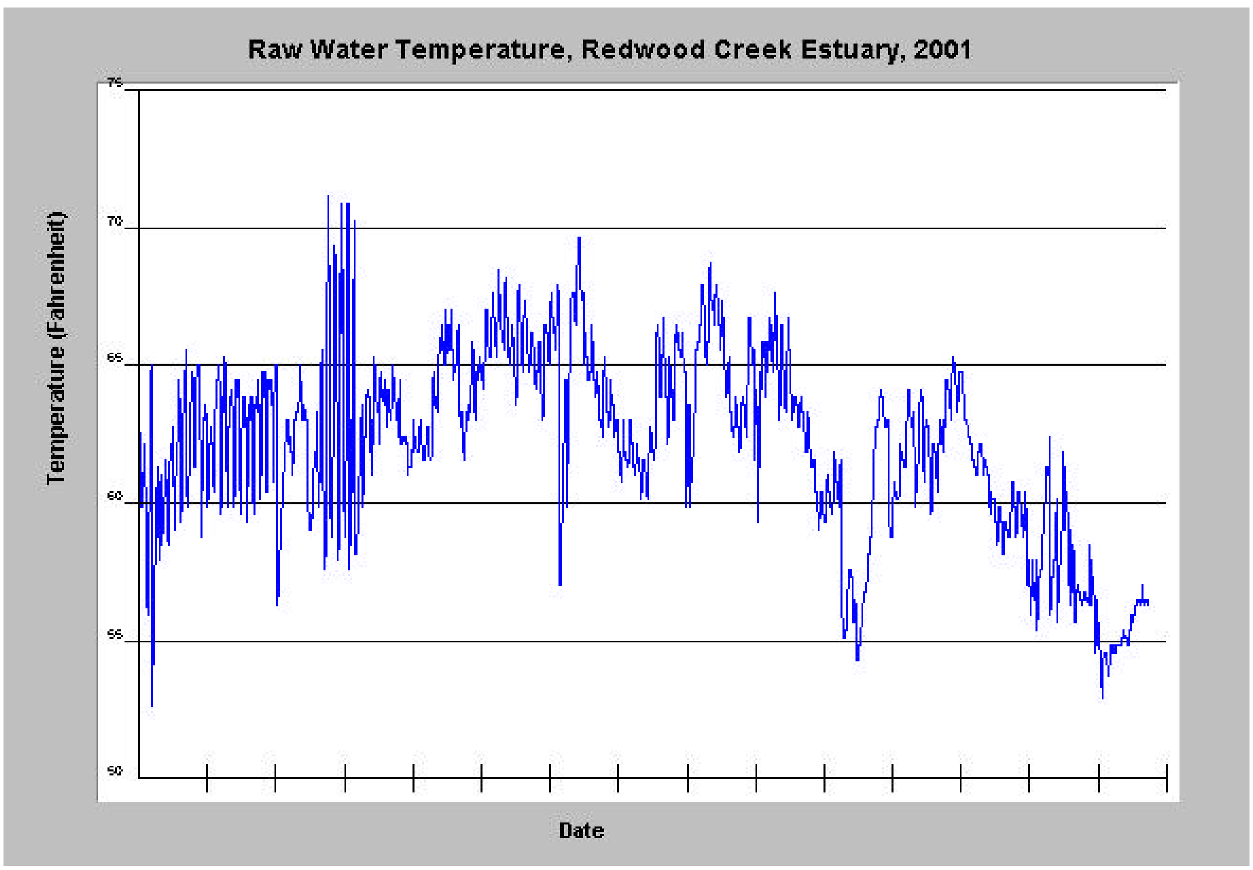


Figure 14: Raw temperature plotted in KRIS for 2001 for site at Redwood Creek Estuary. Data source: RNSP (2001)

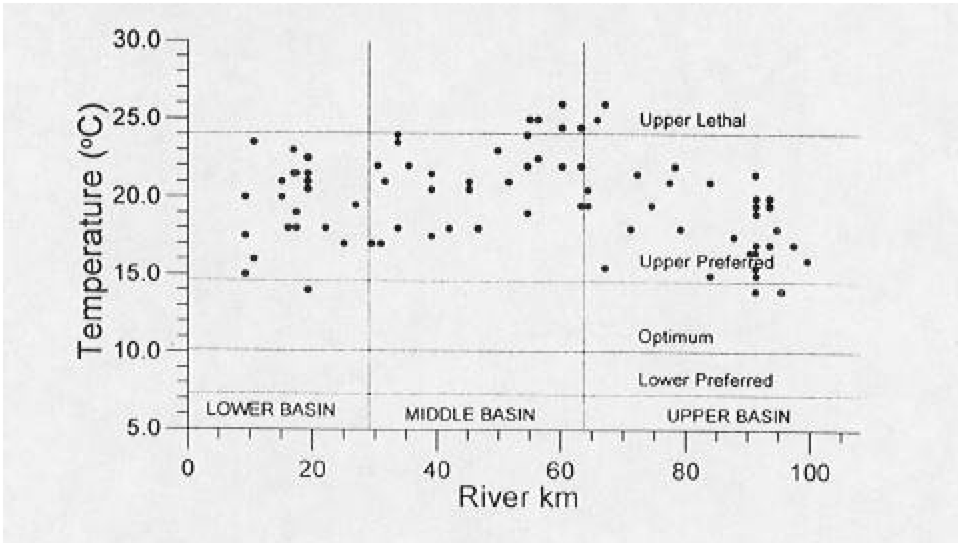


Figure 2: From Ozaki, et al (1999) "Ranges of mainstem surface water temperature at locations along Redwood Creek for summer-fall 1980 and 1981. Temperatures were measured from 0700h to 2000h. Temperature preferences referred to on the graph are for juvenile steelhead trout." Data from Anderson (1988)

Figure 31: Maximum MWATs for the period of record, 1996-2001, for Upper Redwood Creek overlaid on the vegetation layer from USFS LandSat imagery.

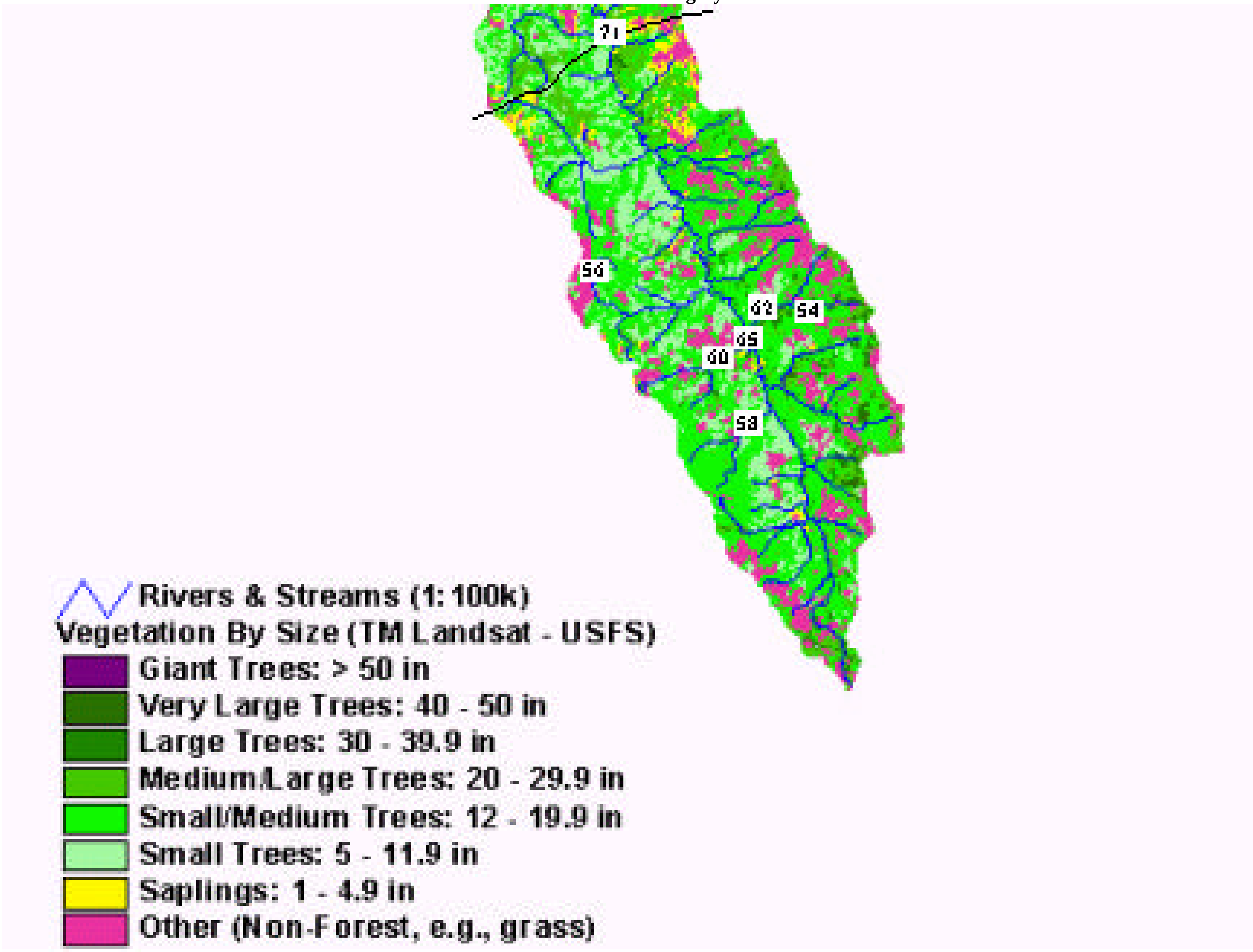


Figure 30: Maximum MWATs for the period of record, 1974-2001, for Middle Redwood Creek overlaid on the vegetation layer from USFS LandSat imagery.

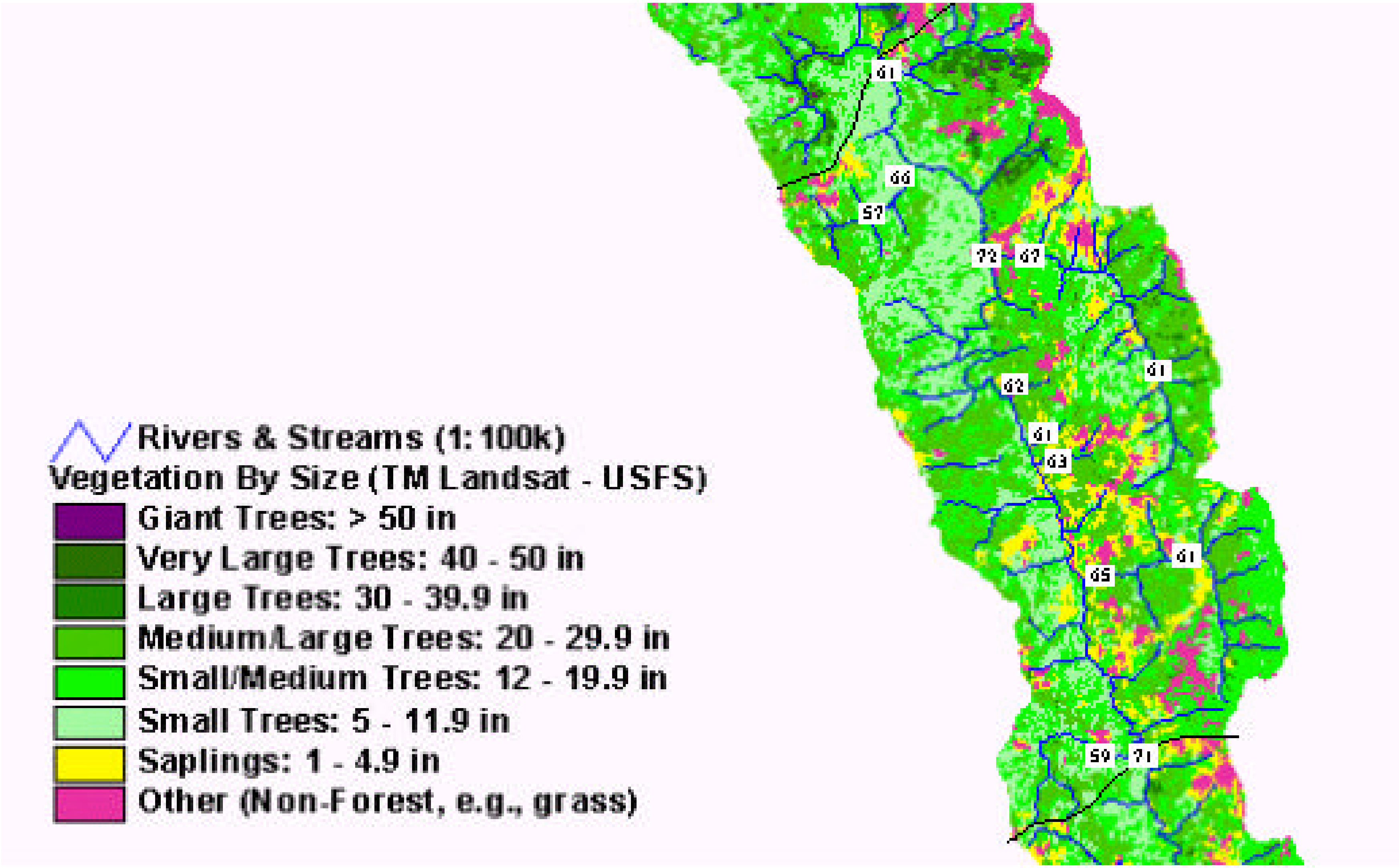
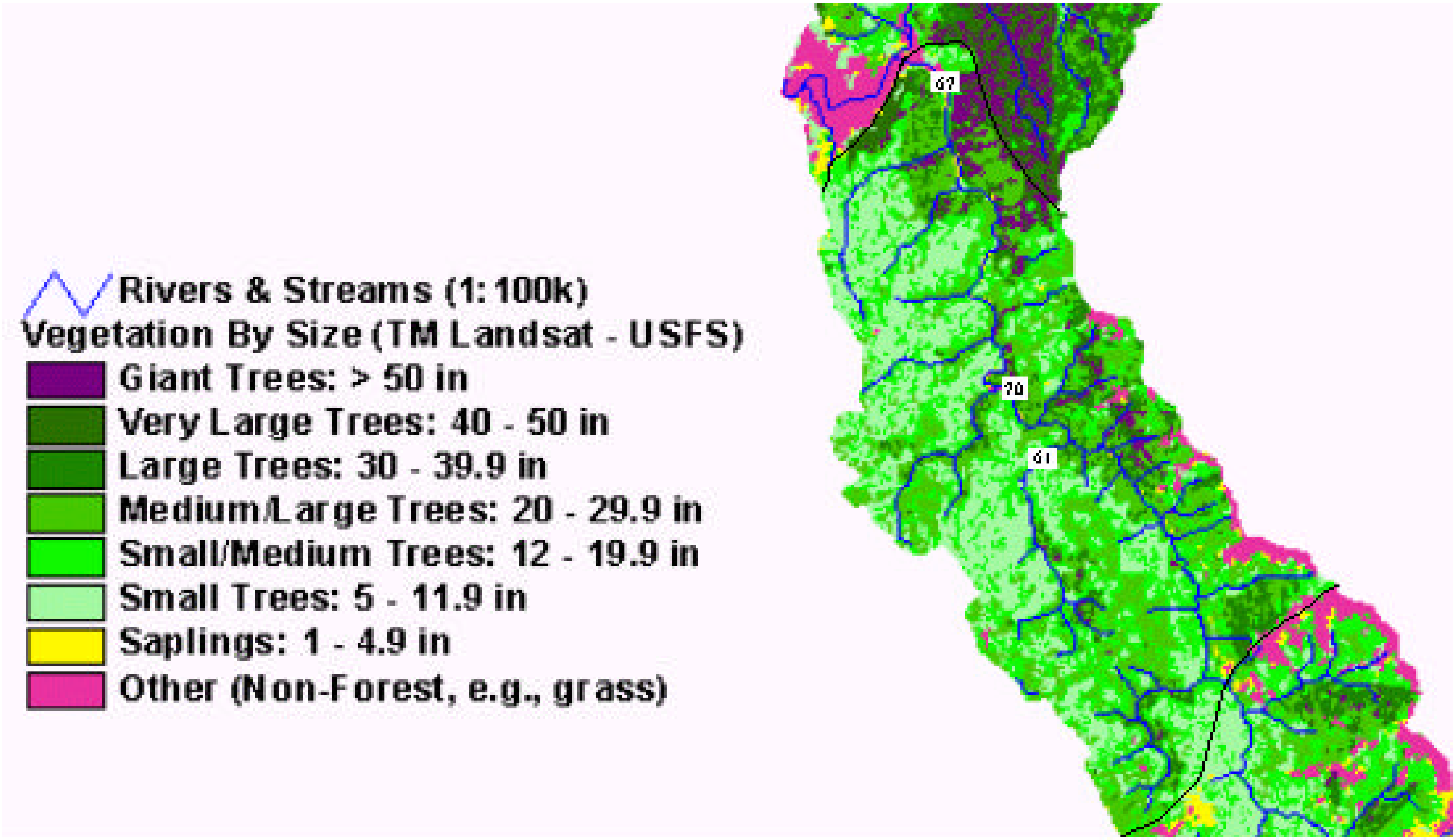


Figure 26: Maximum MWATs for the period of record, 1996-2001, for Lower Redwood Creek overlaid on the vegetation layer from USFS LandSat imagery.



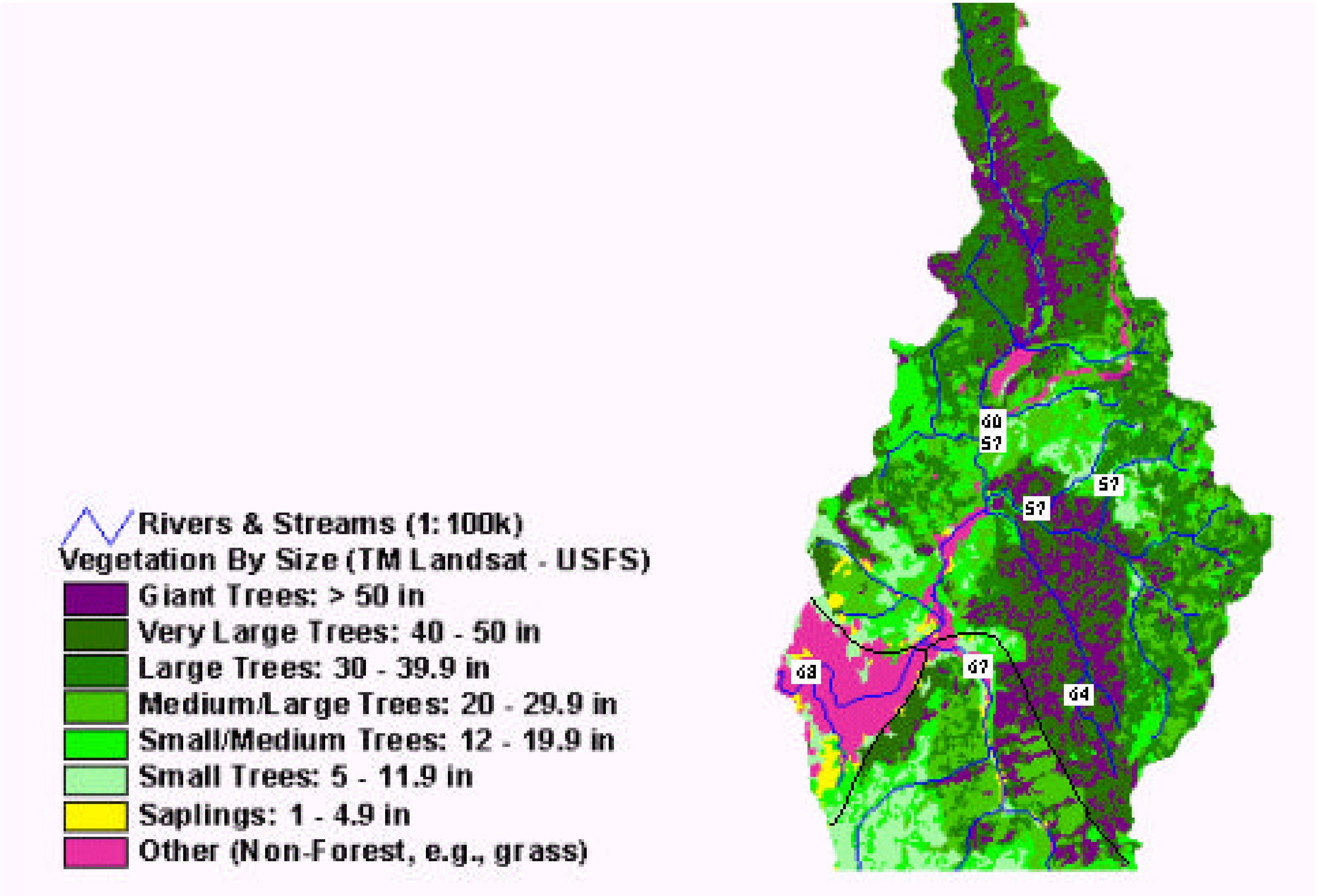


Figure 19: Maximum MWATs for the period of record, 1974-2001, for Prairie Creek and the Estuary overlaid on the vegetation layer from USFS LandSat imagery.

Redwood Creek Watershed Analysis Update 1999

Redwood Creek near Blue Lake (OKN) (RWC)

Water Year	Peak Flow (cfs)	Streamflow (acre feet)	Streamflow (tons)	Suspended Sediment (tons)	Suspended Sediment (tons/mi²)
1993	5,185	94,204	186,854	125,684	1,870
1994	2,209	37,713	74,804	14,377	214
1995	6,205	129,757	275,374	268,096	3,990
1996	8,884	118,505	235,056	505,855	7,528
1997	7,052	102,062	202,440	388,040	5,774
1998	7,001	122,197	242,377	273,855	4,075
1999	4,469	107,811	213,844	90,431	1,346

Lacks Creek (LAC)

Water Year	Peak Flow (cfs)	Streamflow (acre feet)	Streamflow (tons)	Suspended Sediment (tons)	Suspended Sediment (tons/mi²)
1992	435	9,377	18,600	310	18
1993	2,645	33,117	65,688	12,513	740
1994	835	10,754	21,331	868	51
1995	1,279	32,062	63,596	6,809	403
1996	3,017	30,192	59,886	14,348	849
1997	4,391	25,056	49,699	59,292	3,508
1998	1,872	20,519	40,700	14,889	881
1999	5,808	24,028	47,660	36,018	2,131

Panther Creek (PAN)

Water Year	Peak Flow (cfs)	Streamflow (acre feet)	Streamflow (tons)	Suspended Sediment (tons)	Suspended Sediment (tons/mi²)
1992	87	2,112	4,190	38	6
1993	306	11,187	22,189	2,693	444
1994	133	4,132	8,195	112	18
1995	259	10,977	21,772	1,630	269
1996	505	10,363	20,556	7,729	1,273
1997	2,021	10,345	20,520	39,706	6,541
1998	518	7,706	15,285	5,382	887
1999	519	9,478	18,800	4,364	719

Coyote Creek (COY)

Water Year	Peak Flow (cfs)	Streamflow (acre feet)	Streamflow (tons)	Suspended Sediment (tons)	Suspended Sediment (tons/mi²)
1992	284	4,451	8,829	332	43
1993	1,084	17,128	33,974	13,380	1,720
1994	606	7,428	14,734	3,300	424
1995	775	16,228	32,189	5,662	728

Little Lost Man Creek (LLM)

Water Year	Peak Flow (cfs)	Streamflow (acre feet)	Streamflow (tons)	Suspended Sediment (tons)	Suspended Sediment (tons/mi²)
1993	143	4,837	9,595	156	45
1994	102	1,918	3,804	59	17
1995	370	4,594	9,112	635	184
1996	498	5,054	10,024	910	263
1997	639	5,760	11,426	1,044	302
1998	382	7,266	14,413	768	222
*1999	978	5,743	11,391	3,013	871

Redwood Creek at Orick (ORK) (RWC)

Water Year	Peak Flow (cfs)	Streamflow (acre feet)	Streamflow (tons)	Suspended Sediment (tons)	Suspended Sediment (tons/mi²)
1993	11,700	433,132	859,117	388,111	1,396
1994	7,798	167,403	332,045	73,070	263
1995	18,564	461,206	914,802	751,906	2,705
1996	31,660	490,647	973,199	1,080,307	3,886
1997	40,276	459,449	911,318	1,563,727	5,625
1998	19,916	465,682	923,680	1,004,797	3,614
*1999	31,026	473,750	939,683	1,099,292	3,954

*** 1999 LLM Estimated Q data 11/21/99-12/10/99.**

Table 5: Current flow and suspended sediment data from gaging stations monitored by the RNSP. Tables compiled by RNSP (1997

Figure 32: Map of macroinvertebrate sampling locations from Averett and Iwatsubo (1974) study.

R2 GEOMORPHIC PROCESSES AND AQUATIC HABITAT, REDWOOD CREEK BASIN, NORTHWESTERN CALIFORNIA

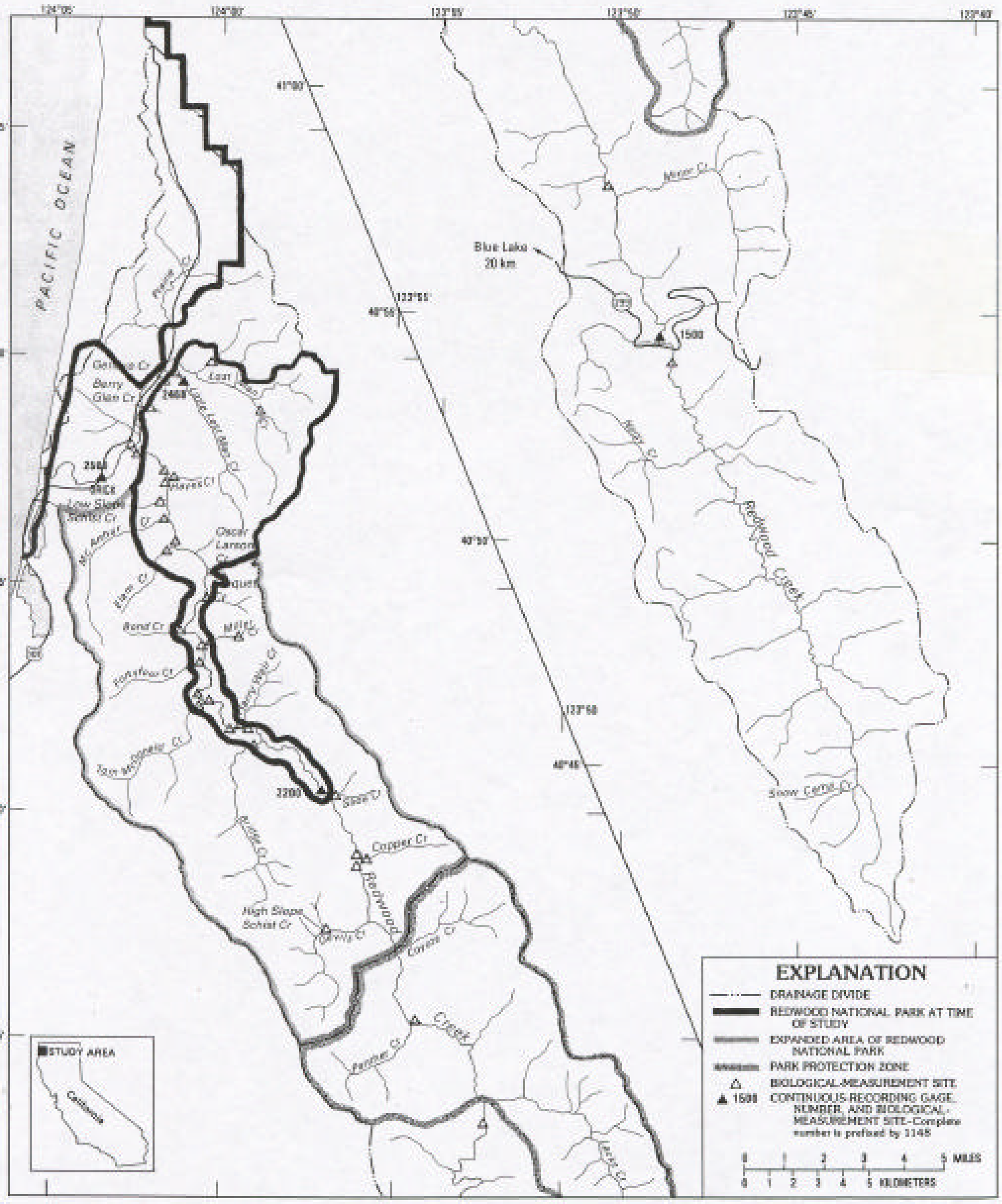


FIGURE 1.—Redwood Creek drainage basin showing main tributaries and sampling sites.